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ADVANCED INTEGRATED FIGHTER COCKPIT STUDY

D. R. Zipoy, et al

Boeing Company

Prepared for:

Air Force Flight Dynamics Laboratory

June 1971

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D. R. Zipoy, S. J. Premselaar, Capt. N. A. Kopchick

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- o Volume I - "System Development" (IIPACS-1)
- o Volume II - "Systems Analysis" (IIPACS-1)
- o Volume III - "Degraded Mode Analysis" (IIPACS-2)

Within the context of the initial study, a composite mission profile and scenario are presented to define the operational requirements for the system concept. Airplane configuration and performance are described, and the characteristics and capabilities of the on-board avionics are summarized. A full-sized, single-place cockpit mockup and three basic interior configurations have been fabricated to reflect study results and to serve as evaluation tools.

The second study, "IIPACS Degraded Mode Analysis," updates the concepts defined in the initial effort and includes analyses of contingency operations. Controls and displays resulting from the analyses are described, and mockups are fabricated and available for evaluation.

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Degraded Mode						
Displays						
Electronic Display						
Energy Management						
Functional Flow Diagram						
Integrated Avionics						
Integration						
Sidearm Controllers						
Stores Management						
System Analysis						
Weapon Delivery						
Workload						

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D. R. Zipoy
S. J. Premselaar
The Boeing Company
Military Airplane Systems Division

N. A. Kopchick, Capt.
USAF
Air Force Flight Dynamics Laboratory

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Air Force Flight Dynamics Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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FOREWORD

This technical report documents the results of work conducted under USAF Contract No. F33615-69-C-1544 and Contract No. F33615-70-C-1832 by Advanced Crewstation Technology Laboratory personnel, Military Airplane Systems Division, The Boeing Company, Seattle, Washington. The objective of this work was to develop a concept for the crewstation development of an advanced fighter aircraft based on 1980-1985 technology.

The contracts were initiated jointly under Project No. 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles", which is managed by Mr. John H. Kearns, III, as Project Engineer and Principal Scientist for the Flight Deck Development Branch (FGR), Flight Control Division, Air Force Flight Dynamics Laboratory, and under Project 4167, "Integrated Avionics", which is managed by Mr. Richard D. Alberts, as Project Engineer for the Plans Office (XP), Air Force Avionics Laboratory. The work was performed as a part of Task 6190 21, "Advanced Integrated Fighter Cockpit Development Program", under the guidance of Mr. Robert R. Davis, Group Leader, and Capt N. A. Kopchick (FGR) as Task Engineer.

Acknowledgement of significant contributions during the first phase of the program (entitled "Integrated Information Presentation and Control System Study") goes to D. R. Zipoy, Principal Investigator; S. J. Premselaar, Lead Engineer, for systems analysis and cockpit configuration; I. L. Belyea for display design and cockpit human factors criteria; H. J. Hall, Jr., for cockpit and controller design as well as design and fabrication of mockups; R. E. Gargett for system analysis and avionics concepts; A. P. Augustiny for translation of the mockup designs into working drawings; F. V. Lane for timeline/workload evaluation; B. D. Nelson for airplane configuration concept and performance; and Capt N. A. Kopchick, Technical Monitor for the Air Force.

Significant contributions during the second phase of the program (entitled "IIPACS - Degraded Mode Analysis") were submitted by S. J. Premselaar as Principal Investigator; J. G. Hatcher for avionics design concepts and degraded mode analyses; R. L. Richardson for design concepts in aircraft systems and degraded mode analyses; R. L. Kinnaman for avionics and store management concepts; W. D. Smith for workload analyses; V. Foisey for the reliability study and failure ranking; and Capt N. A. Kopchick, Technical Monitor for the Air Force.

The work effort covered the period from March 1969 through March 1971. This report was submitted by the authors in April 1971 for publication as an AFFDL Technical Report. This report is being reissued in 1974 for administrative reasons.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Richard L. Ravenelle

RICHARD L. RAVENELLE
Lt Col, USAF, Chief
Flight Deck Development Branch
Flight Control Division
AF Flight Dynamics Laboratory

ABSTRACT

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Within the context of the initial study, a composite mission profile and scenario are presented to define the operational requirements for the system concept. Airplane configuration and performance are described, and the characteristics and capabilities of the on-board avionics are summarized. A full-sized, single-place cockpit mockup and three basic interior configurations have been fabricated to reflect study results and to serve as evaluation tools.

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LIST OF ABBREVIATIONS

AA, A/A--air-to-air

AAA--anti-aircraft artillery

ac--alternating current

A/C--aircraft

ACK--acknowledge

ACSA--auxiliary coded switch assembly

ADDR--air data dead reckoning

ADF--automatic direction finding

A/G--air-to-ground

AFCS--automatic flight control system

AGLR--air-to-ground ranging

AHRS--attitude heading reference system

AIs--airborne interceptors

AILA--airborne instrument landing approach

ALT--altitude hold

APU--auxiliary power unit

ARM--anti-radar missile

ATA--automatic target acquisition

ATF--automatic terrain following

AWACS--airborne warning and control system

BAC--battle area command

BARO--barometric

BCN--beacon

BDA--battle damage assessment

BITE--built-in test equipment

BRG--bearing

BS--boresight

BSD--battle situation display

CCC--central computer complex

CEP--circular error probability

cg--center of gravity

C&I--communication/identification

C/L--command link

CM--countermeasure

CMD--command

CMDS--countermeasures dispensing system

CNI--communications, navigation, and identification

CP--checkpoint

CRT--cathode ray tube

CSA--coded switch assembly

CSS--control stick steer

CSS--coded switch system

DBS--Doppler beam sharpening

dc--direct current

DIS--Doppler inertial satellite

D/L--data link

DME--distance measuring equipment

EAS--equivalent airspeed

ECD--energy control director

ECM--electronic countermeasures

ECS--environmental control system

EL--electroluminescence

EMP--electromagnetic pulse

E-O--electro-optical

EW--early warning

FAA--Federal Aviation Administration

FAC--forward air controller

FLIR--forward-looking infrared

FMACS--failure monitor and control system

FOV--field of view

GCA--ground control approach

GCI--ground control intercept

GM--ground map

GMS--ground map squint

GS--ground speed

H--altitude

HARS--heading and attitude reference system

HF--high frequency

HSD--horizontal situation display

HTT--hard target tracking

HUD--head-up display

IEGS--integrated engine-generator system

IFC--instrument flight conditions

IFF--identification, friend or foe

IFR--in-flight refueling

IIPACS--integrated information presentation and control system study

IKC--integrated keyboard control

ILM--independent landing monitor

ILS--instrument landing system

IMS--independent monitoring system

IR--infrared

ITEMS--integrated total energy management system

ITO--instrument takeoff

LED--light emitting diode

LF--low frequency

LLLTV--low light level television

LORAN--long range navigation

LR--long range

LRU--line replaceable unit

MF--medium frequency

MMR--multimode radar

MPD--multipurpose display

MTI--moving target indicator

NAVSAT--satellite navigation

NAVSTEER--navigation steer

NFOV--narrow field of view

NM--nautical mile

nmi--nautical mile

OCS--off-center sector

PAL--prescribed action link

LIST OF ABBREVIATIONS (Contd)

PP--present position

PPI--plan position indicator

PPR--preplanned route

PRF--pulse repetition frequency

PW--pulse width

RF--radio frequency

RHAW--radar homing and warning

RTB--return to base

SAM--surface-to-air missile

SAS--stability augmentation system

SAT--satellite

SIGINT--signal intelligence

SL--sea level

SMS--stores management system

S/N--signal to noise ratio

SPD CONT--speed control

STU--signal transfer unit

SUAWACS--Soviet Union airborne warning and control system

TAS--true airspeed

TF/TA--terrain following/terrain avoidance

TGT--target

TH--true heading

T/R--transmit and receive

V--velocity

VFC--visual flight conditions

VHF--very high frequency

VSD--vertical situation display

WCS--weapon control system

WECC--workload evaluation for cockpit crews

WFOV--wide field of view

X-hair--crosshair

αN--alphanumeric

SECTION I

INTRODUCTION

The U. S. Air Force let two contracts to The Boeing Company to develop an integrated presentation and control system concept that will cast the man-machine system into an effective tactical fighter weapon system during normal and degraded mode operations. These studies represent elements of an Air Force plan to develop an effective tactical fighter weapon system for the 1980 time period in deference to the requirements generated by the following postulation.

Developmental trends in high-performance aircraft and avionics are expected to result in a proliferation of controls and displays that demand an unprecedented level of occupation by the pilot--particularly those pilots flying advanced tactical fighters. Mission requirements for future tactical fighters will dictate system capabilities that will cope with not only the diverse environs of geography and weather both day and night, but also with the various gradations of cold, hot, and limited wars. The tactical fighter's arsenal must then range from guns to nuclear weapons with the gamut of conventional weapons between.

To be effective in its role, the tactical fighter weapon system must be capable of pinpoint navigation and high-accuracy weapon delivery. Additional complications include weapon deliveries at low altitude and supersonic speeds requiring a highly discriminatory and rapid target acquisition capability.

Technology in the 1980 time period will enable production of tools necessary to complete a complex mission; however, the pilot faces the overwhelming task of collecting, collating, integrating, and interpreting a mass of information during normal operations.

A system designed to serve the complex needs of an advanced tactical fighter may be expected to be vulnerable to equipment failure and battle damage. The weapon system must enjoy a high probability of survival and mission completion to be effective. As such, the capability to continue operations after sustaining failures to an identifiable level is considered mandatory.

Contingency operations impact the pilot's workload and may jeopardize mission success. The tactical fighter must have the controls and displays necessary to ensure that an effective weapon system is provided during all modes of operation.

An integrated control and display system that presents only essential information in a format that can be translated easily by its user into direct control inputs must be developed. Many of the pilot's routine and repetitive tasks suggest automation to alleviate his workload.

SECTION II

SUMMARY

Two studies, "Integrated Information Presentation and Control System Study," and "IIPACS Degraded Mode Study," herein referred to as IIPACS-1 and IIPACS-2, have resulted in a systematic development of a tactical fighter cockpit concept for use in the 1980 time period. The system presented provides the pilot full capability for effective on-line overall weapon system management for normal and degraded mode operations.

The systematic approach used in the IIPACS-1 study is diagrammed in Figure 1. The level of automation required to achieve the desired results is depicted in Figure 2. System concepts, the aircraft seen in Figure 3, and three cockpit configurations, Figures 4, 5, and 6, represent the results of this study.

Figure 7 presents the program flow chart for IIPACS-2. The results of the updating of IIPACS-1 and the degraded mode analysis may be seen by comparing the IIPACS-1 wrap-around cockpit layout, Figure 8, and the IIPACS-2 configuration, Figure 9. A digest of the updated IIPACS avionics system is presented on the pages following. The IIPACS-2 interface diagram and cockpit arrangement are enclosed in a holder attached to the back cover of this document.

The conclusions reached on the basis of this study indicate that the concepts presented will, if mechanized, result in a weapon system that meets the needs for a tactical fighter of the 1980 time period.

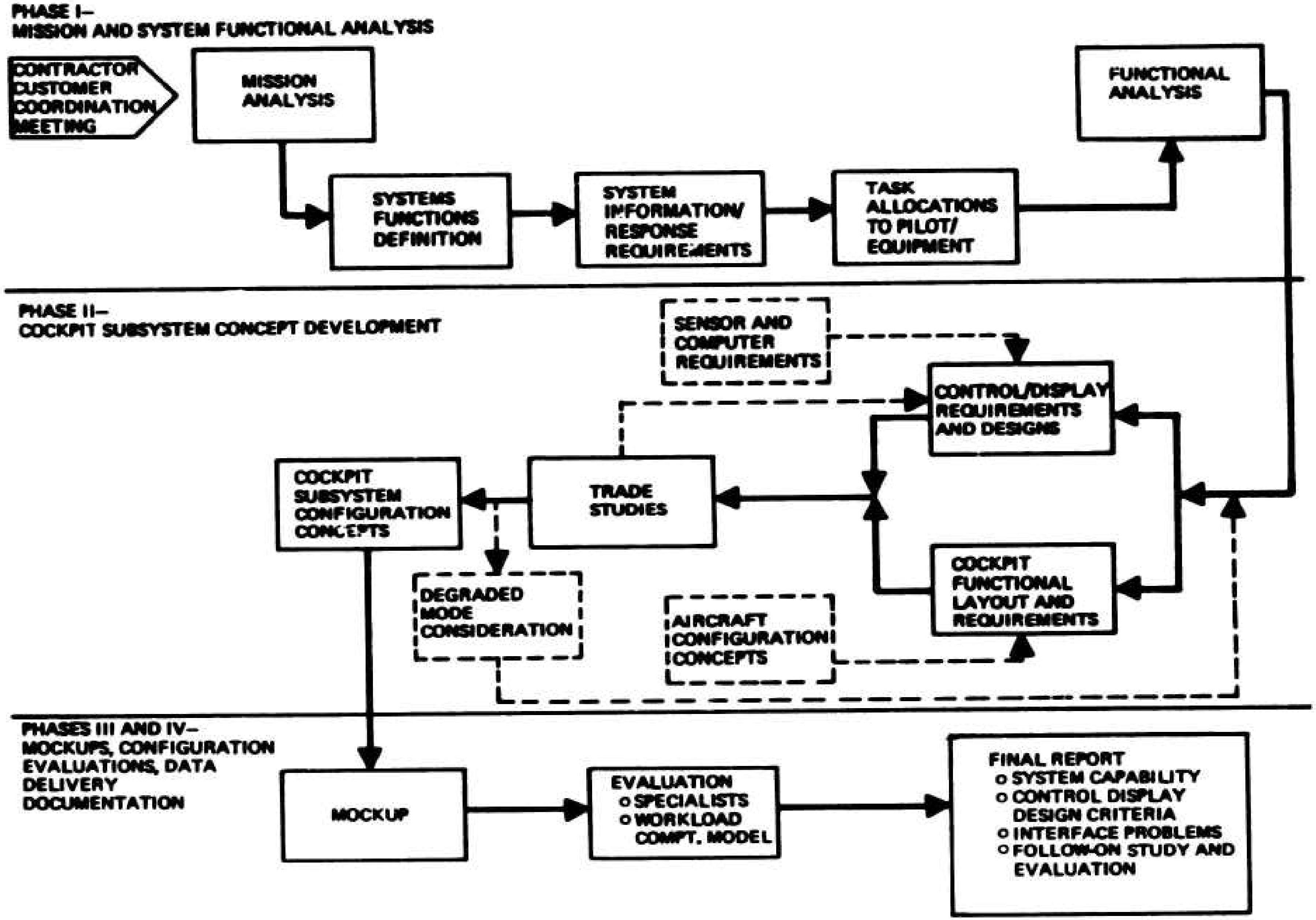

Figure 1. II PACS-1 Program Flow Chart

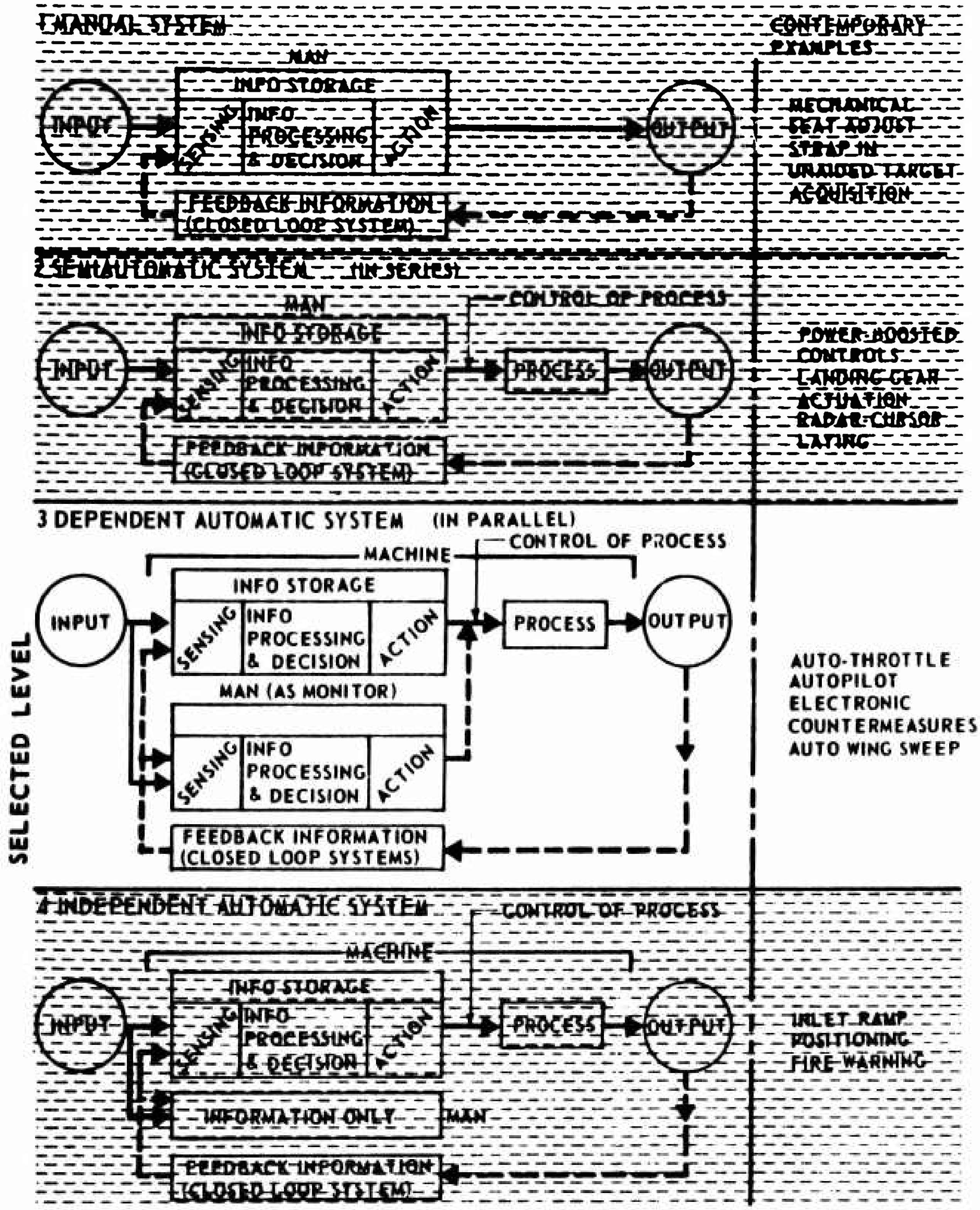

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Figure 2 Man Machine Relationship

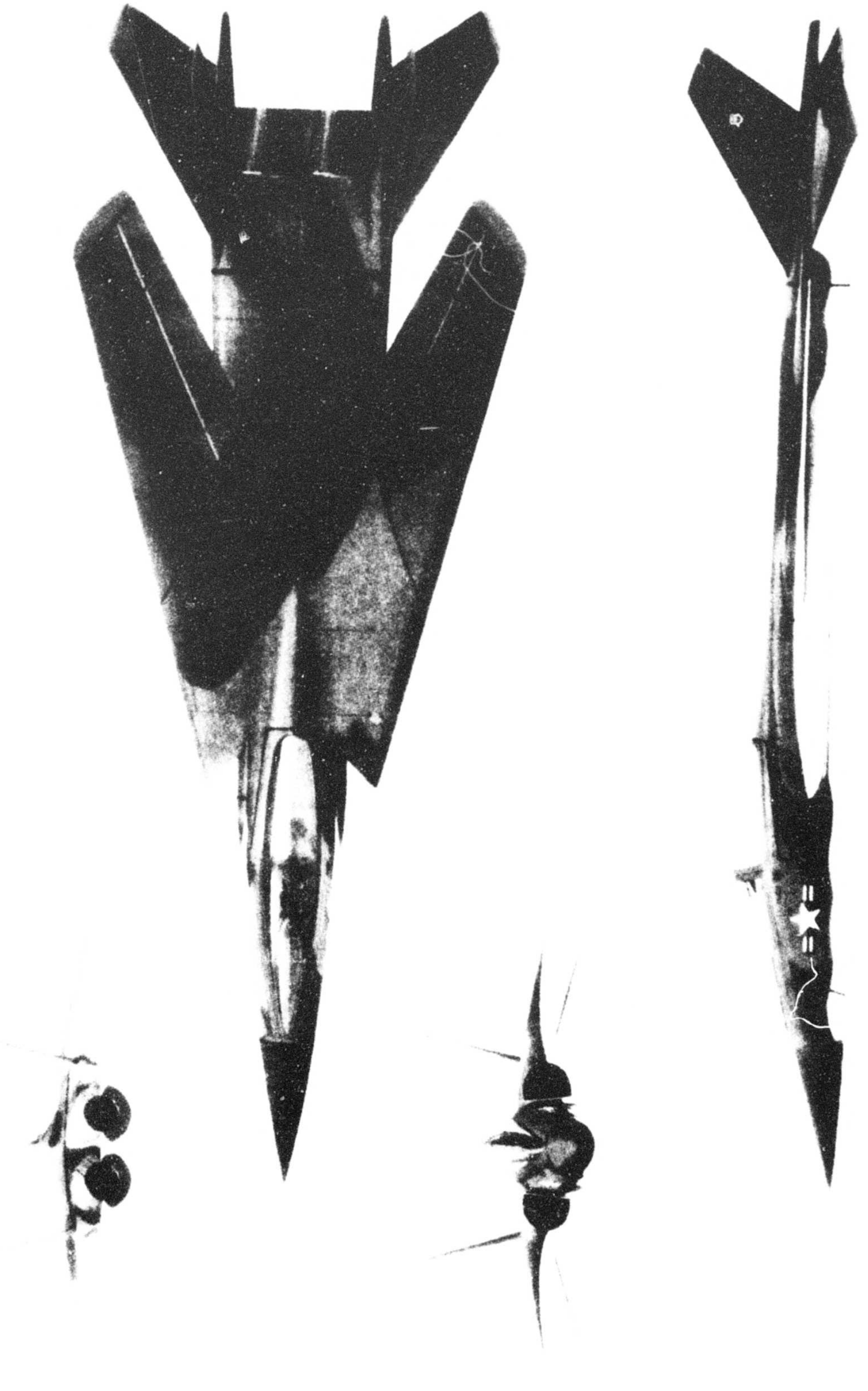


Figure 3. Study Aircraft

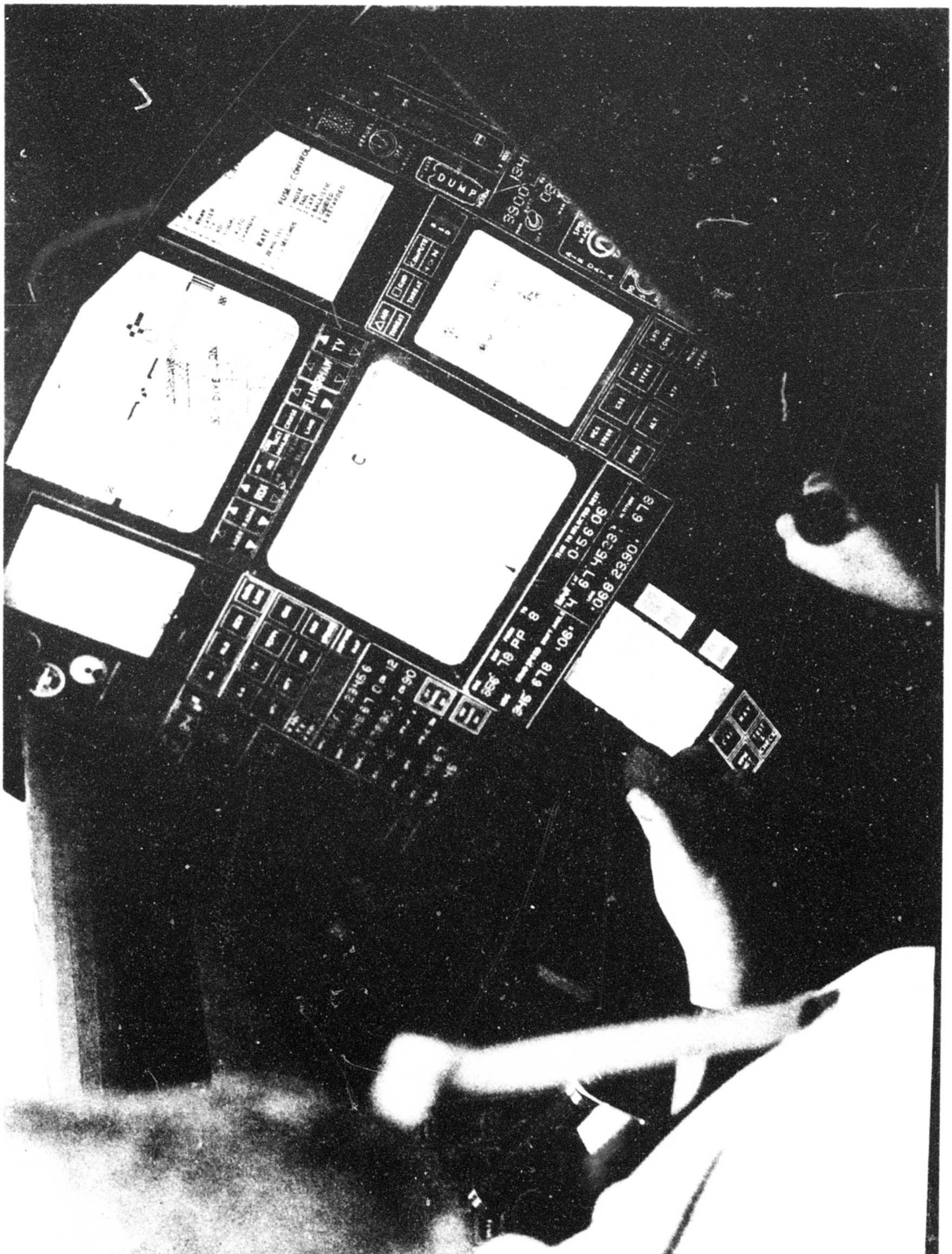


Figure 4. Center Stick Cockpit

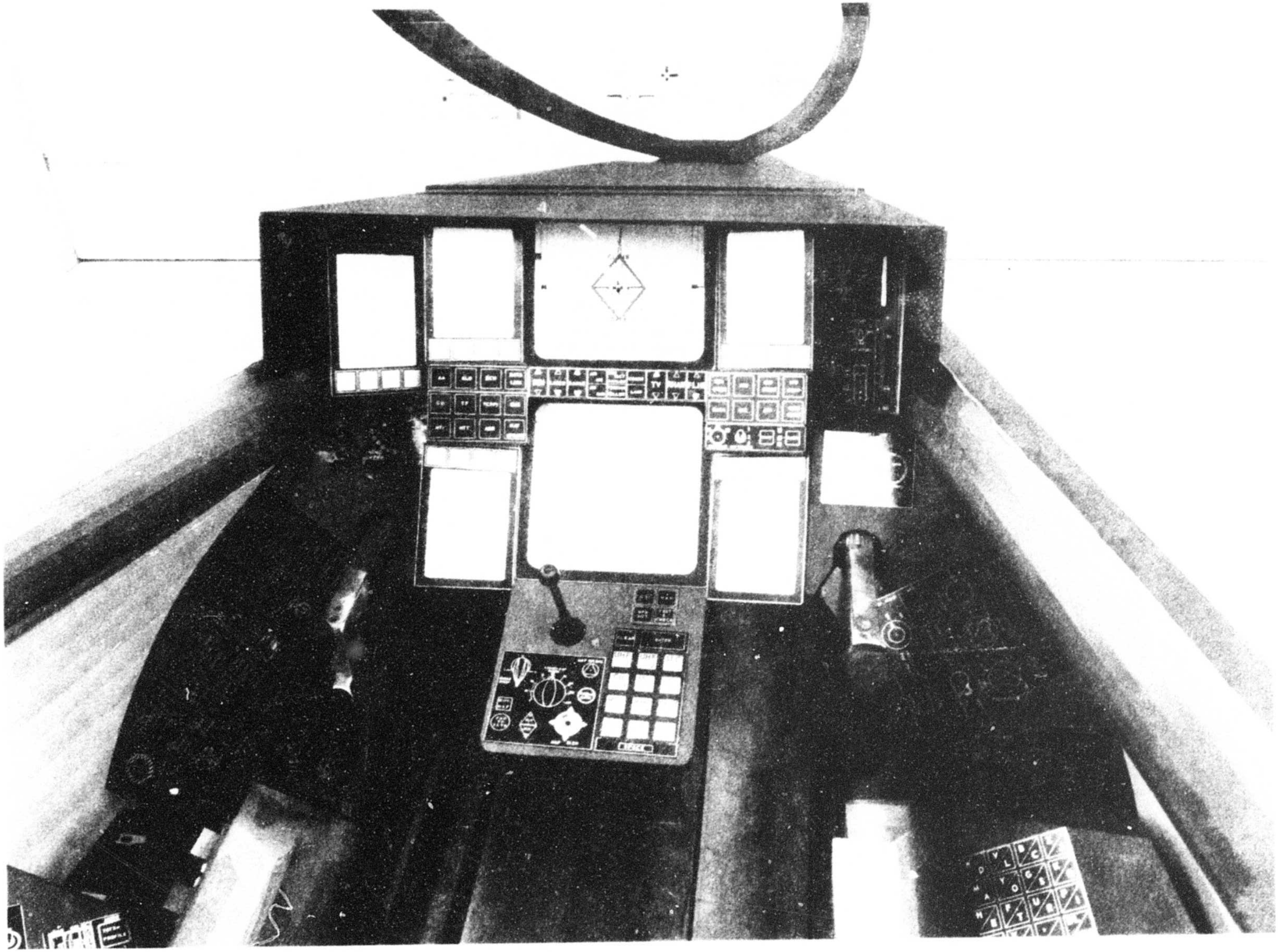


Figure 5. Panel Mounted Control Handle Cockpit

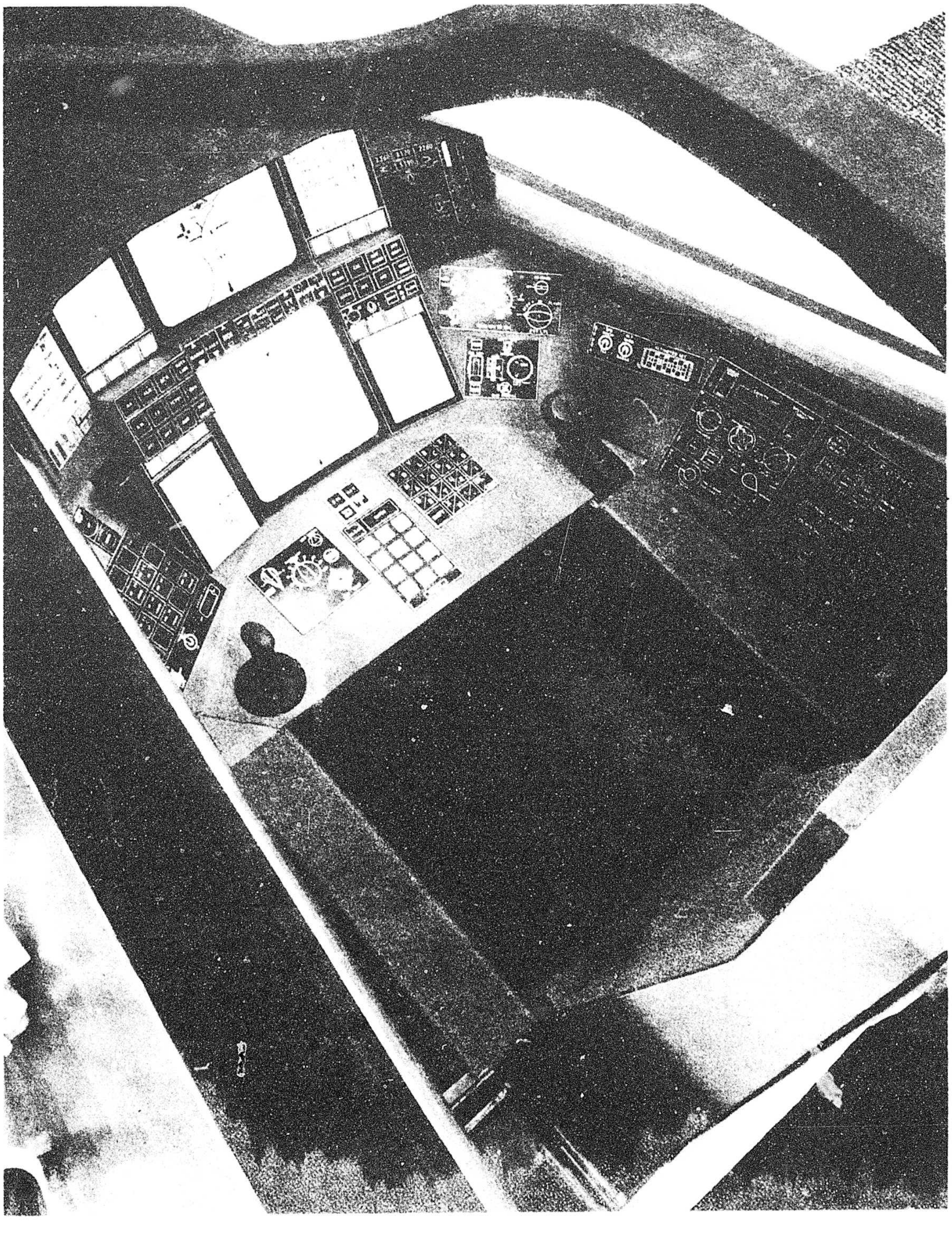


Figure 6. Wraparound Cockpit

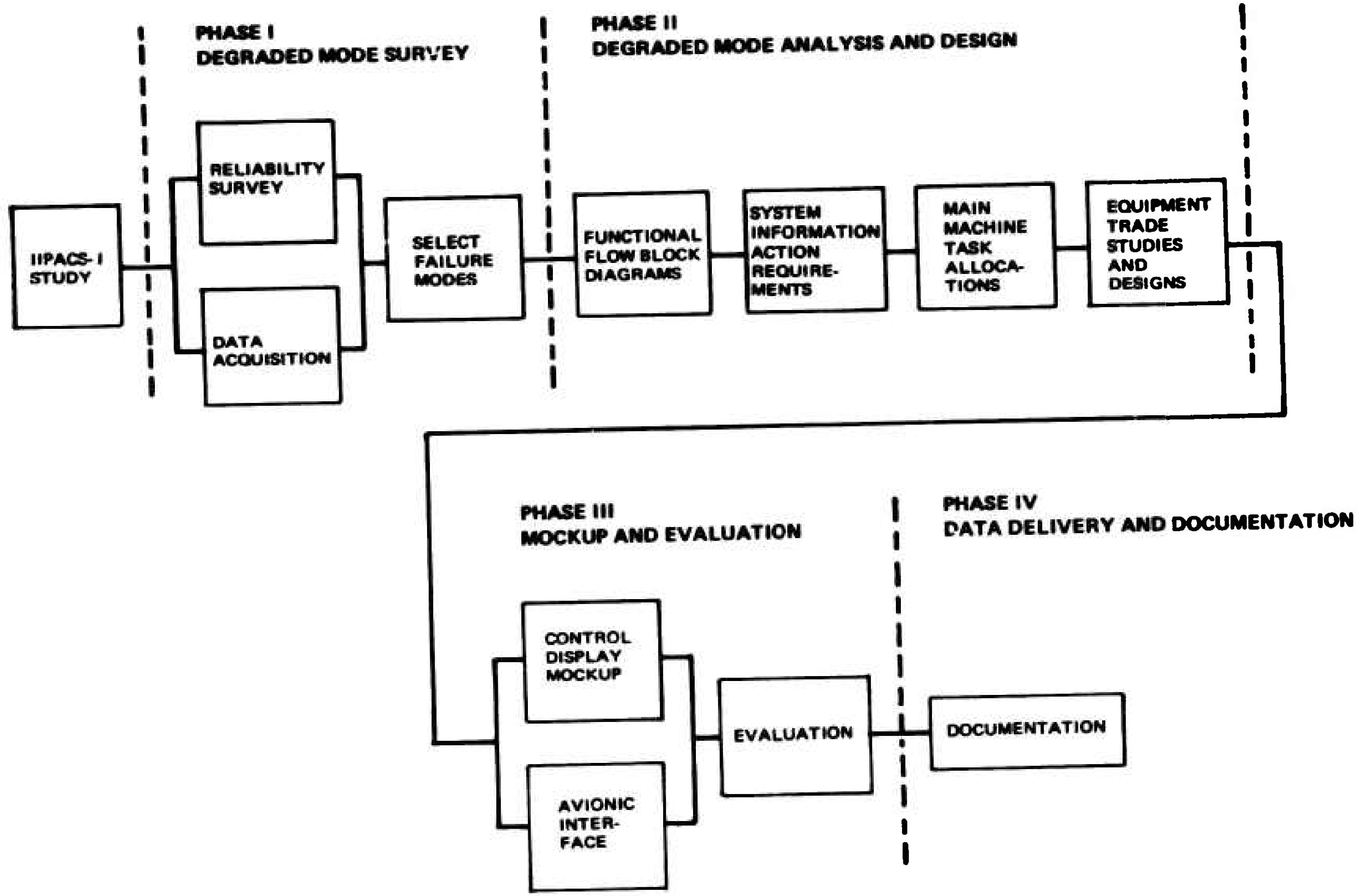


Figure 7. IIPACS-2 Program Flow Chart

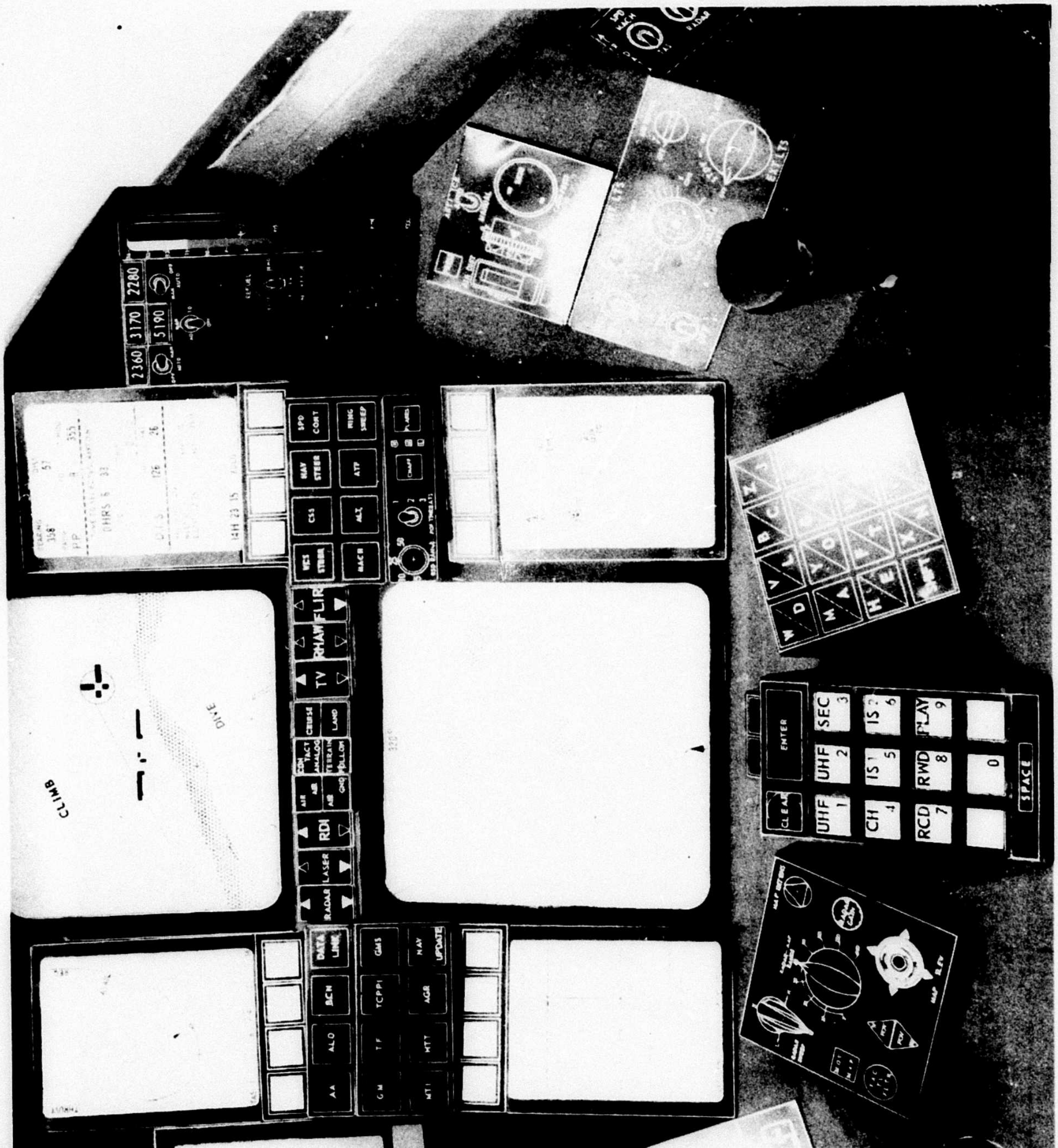


Figure 8. IIPACS-1 Wraparound Cockpit

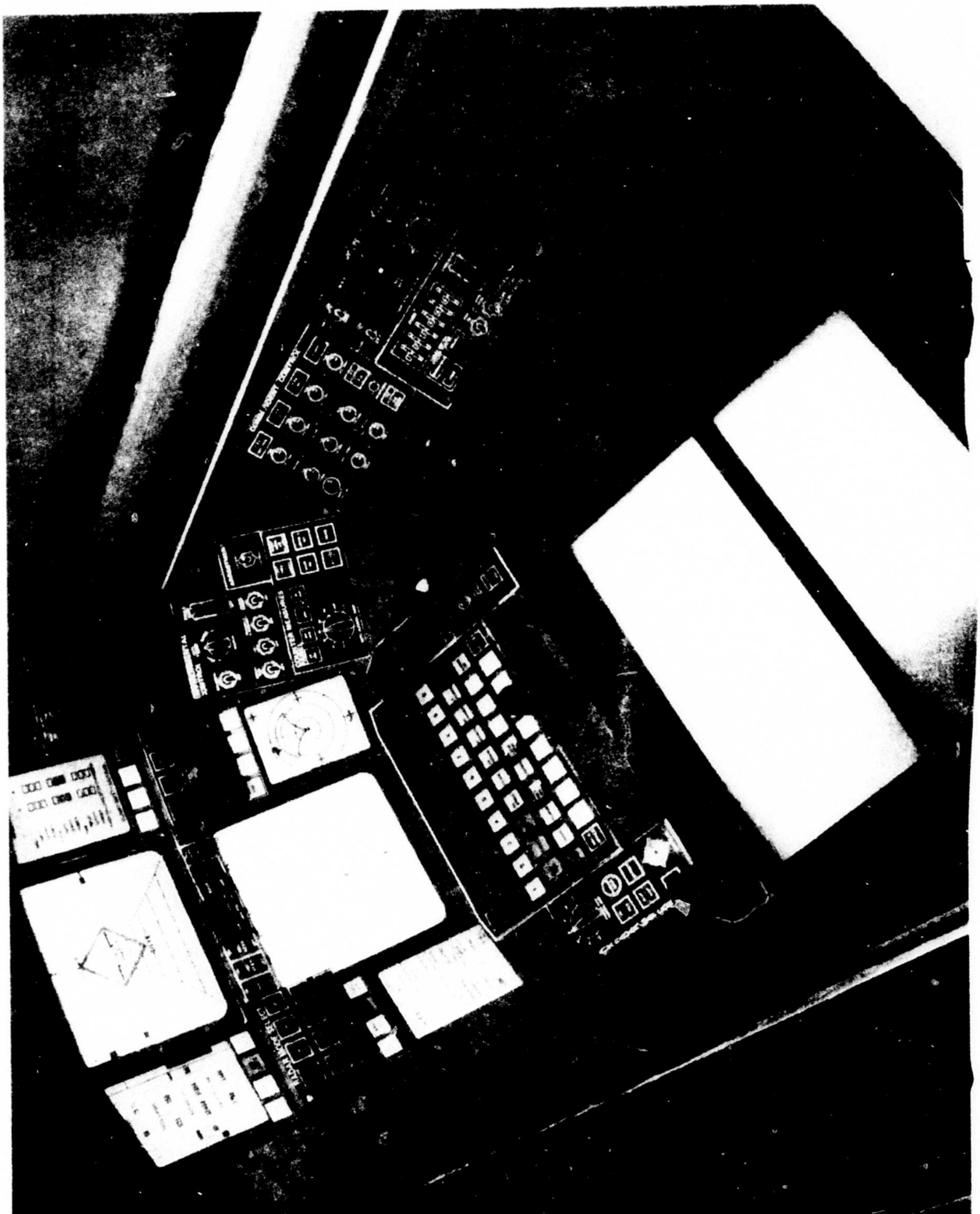


Figure 9. HPACS-2 Wraparound Cockpit

FAILURE MONITOR AND CONTROL

Equipment	General Description
Failure Monitor and Control System (FMACS)	A programmed control system that performs on-board test and checkout function of all aircraft systems. While airborne these functions include system status to the pilot and to remote monitors via data links; provide warning of flight safety conditions, automated corrective actions, and display of these actions; and provide notification of impending failures. On the ground, these functions include automatically controlled preflight, flight/mission readiness, and fault isolation tests.

COMMUNICATION/IDENTIFICATION

Equipment	General Description
HF	Basic long range air-to-air and air-to-ground communications, with voice AM/SSB provisions; provides backup to Satellite relay link during Spread-Spectrum communications.
Spread-Spectrum Communications (SHF Band)	Basic secure voice/data link communication system between the IIPACS Aircraft and Command and Control; provides additional functions of "Guard" and IFF backup; computer programmed for spherical coverage--omni or directional beam control; compatible with integrated conformal/phased array antenna system.
Data Link	Provides data link for commands, messages, systems status (FMACS), processed sensor video, and battle damage assessment recorded data when transmitted via spread-spectrum communications.
Satellite	Relays RF information (voice/data) between IIPACS Aircraft and Command and Control at the spread spectrum frequencies.
IFF (Transponder)	Provides omnidirectional RF-coded response in answer to a spread-spectrum or radar interrogation pulse from a ground or airborne station.
IFF (Interrogator)	Interrogates other aircraft automatically at specified bearings when directed by other on-board systems through the central computer. Supplies coded interrogation instructions to the Multimode Radar and Spread-Spectrum Communications during air-to-air encounters. In addition to "automatic" interrogation by the computer, means are provided for "manual" interrogation with either Dir. Comm. or Radar, after the target has been designated with the cursor.

FIRE CONTROL SUBSYSTEM EQUIPMENTS

Equipment	General Description
Multimode Radar	Conformal/planar array operating at X-band. Electronically scanned; electronically stabilized; spherical coverage; operating modes--terrain-following/terrain-avoidance,air-to-air target search/track, missile illumination, high resolution mapping (squint, spotlighting, and doppler beam sharpening), conventional mapping, ground moving target indication, situation, and beacon. Integrated with air-to-air IFF at X-band.
LLLTV	Electrostatic image orthicon with SEC target material and S-20 photosurface; 1000 TV lines resolution reducing to 500 lines at 10 ft-candles illumination; fibre optics image recitification; 18° by 24° total field of view (positionable over 360°) with both optical and electronic zoom to 3:1.
LASER	High power narrow beamwidth pulse type; provides accurate range and range-rate information to the aircraft weapon delivery system when used with LLLTV and FLIR.
FLIR	Passive infrared system operating on the temperature and emissivity of objects against a background; uses a technique known as opto-mechanical scanning; same field of view (18° by 24°) as LLLTV and positionable over 360° azimuth with both optical and electronic zoom to 3:1; uses common optics with LLLTV with scanning at 1024 lines and 30 frames per second.

DISPLAYS

Equipment	General Description
HUD	Fold down storage of combiner glass; 20° vertically by 25° horizontally total field of view; automatic brightness level control; optically flat liquid crystal combiner; unique features of presenting Weapon TV/LLLTV/FLIR on a 1.5-inch elliptical area--focused to infinity; symbology and sensor data can be viewed in either day or night background conditions. The HUD has dual reticle (fixed and slaved) provisions and a built-in 16mm camera for simultaneous recording of all sight displays and the real world.
VSD	A 10-incn diagonal viewing surface; 1,024 TV line direct view color CRT that presents information of flight situation, control, and weapon delivery in an integrated form; uses digital display techniques data presantation in raster scan; CRT uses image enhancement techniques that will ensure proper visibility under all ambient light conditions; subsystem operational MTBF of 2,500 hours.
HSD	A 10-inch diagonal viewing surface interchangeable with the VSD; selectively combines CRT display information with a computer-generated, full-color moving map; provides present position, en route, target and terminal information as the situation dictates; composite combinations of full-color map and processed sensor data (MMR, LLLTV/FLIR, and Battle Situation) are available, depending on pilot selection and flight mode; oriented with either north or aircraft heading at the top of display.

DISPLAYS (Contd)

Equipment	General Description
MPD's	A total of five displays with 3-1/2 by 4-1/2 inch viewing surface are grouped around the VSD and HSD; any one of five stored presentations can be selected manually or automatically; calligraphic information and maps are presented in various colors while sensor information will be in shades of one color.

PENETRATION AIDS

Equipment	General Description
RHAW and IR Warning Receiver	Threat energy sources are primarily in the S- through K-band and in the IR region. Passive receivers are provided to measure threat emission characteristics and threat direction. The central computer complex processes these data and determines threat identity.
RF and IR Jammers	An IR (tail) jammer and RF automatically computer programmed jammers are used to jam primary threat transmissions. Computer programming for the jammers is inserted with the cassette.
Countermeasure Dispensing System	Two dispensing systems, one on each side of the airplane are provided to selectively release a wide variety of prepackaged expendable countermeasures including chaff, flares, and expendable jammers.

CENTRAL COMPUTER COMPLEX

Equipment	General Description
Computer	The computer is extremely reliable because the IIPACS airplane is highly automated. The central computer is functionally integrated for maximum use but it contains separately located components to minimize performance degradation due to localized battle damage. Computer performance estimates are for about one million operations per second using 130,000 memory locations. The minimum level of computing power, acceptable in degraded modes, is about one-half the normal computer size; that is, 500,000 operations per second and 65,000 memory locations.
Interface	Signal processors, buffers, switching circuits and other computer interface elements are included with the central computer complex. Both hard-wired and multiplexed circuits are used. A basic computer and avionics design requirement is to minimize heavy, costly interface.

STORES MANAGEMENT SYSTEM

Equipment	General Description
Coded Switch Control	Replaces the prescribed action link (PAL) for nuclear weapons. Provides a means for manual insertion of the control code for nuclear consent.
Central Logic Unit	Includes interface logic and switching circuits needed to command and to secure status for all weapons. By integrated functions common to all weapons into a single central logic unit, lower cost and weight systems result.
Station Logic Unit	Used with the central logic unit. It includes only uncommon functions for particular weapons. The unit is located at the weapon station and is the only subsystem that must be changed or replaced when a different kind of weapon is loaded on a specific stores station.

NAVIGATION

Equipment	General Description
Inertial Platform	Two inertial measuring units are provided. Associated computations are performed by the central computer complex. Accuracy is improved by including doppler from the multimode radar and by using Kalman error estimates. To minimize errors, inertial, satellite and all other sources of useful navigational data are compared.
Radar Altimeter	A conventional radar altimeter is provided to measure aircraft height above terrain. A second way to measure height above terrain is available with the multimode radar.
Satellite	Satellite navigation (NAVSAT) is the most accurate onboard means for navigation without fix updates. Satellite navigation is used when accurately placed navigational satellites are available. A receiver for satellite signals is provided.
Landing Aids	A receiver is included for ILS. The multimode radar, operating in a passive mode, is used to receive beacon ILM signals. GCA transmissions are received over the data link. The multimode radar, in an active mode, is used for AILA.
Heading and Attitude Reference System (HARS)	For improved accuracy in degraded modes, the HARS is a low quality inertial system. This allows for earth latitude error corrections if inertial system failures exist. With this feature, added navigational redundancy is provided. Including the HARS provides triple redundancy for fail operational performance in critical mission segments.
Air Data	Included are probes for ambient temperature, ambient pressure, dynamic pressure and ram air temperature. Anti-ice provisions are included. Air data computations are performed by the central computer complex
TACAN	Provides range and bearing to a known surface location. Primary use, with aircraft in-talled ground components is

NAVIGATION (Contd)

Equipment	General Description
TACAN (Contd)	for station-keeping and rendezvous. TACAN ground stations in war theaters are limited, and extensive use as a basic navigational method is sometimes restricted to peacetime operations.
Collision Avoidance	Time-frequency system synchronized to a ground station master time source. Transmits precise range, altitude and range rate information to other aircraft where data is analyzed and presented to the pilot as a warning if a collision is imminent.

SECTION III

RESULTS AND DISCUSSION

1. GROUND RULES AND ASSUMPTIONS

The cockpit of the tactical fighter is the focal point for the aircraft's systems and subsystems. Definition of the aircraft and its avionic system is a necessary first step to the development of an integrated control/display complex. The aircraft and avionic systems were developed within the framework of the following ground rules and assumptions:

Ground Rules

- One-man crew
- F-15 M-5 avionics package as a baseline system
- Air-to-ground combat is the primary operational mission
- Time-shared display techniques
- 1980 avionics state of the art
- Pilot retains executive control over an automatic system
- Systems approach in the analysis

Assumptions

- Twin-engine airplane
- Maximum speeds: Mach 2.5 at altitude and 1.5 at sea level
- Air-to-air defense capability (M-5)
- Variable sweep wing
- Conventional takeoff and landing capabilities only
- Digital avionics interface
- System cost, weight, and reliability secondary considerations to crew performance

2. MISSION PROFILE

The mission profile, Figure 10, was developed to determine system requirements. The profile is based on a composite mission and describes the assumed operational capability of the advanced tactical fighter. The lower profile plots time, in hours, on the abscissa against altitude. Significant events along the profile are identified. Mach number, as related to time and task, is indicated in the plot directly over the mission profile.

For clarity, a plan view and a three-dimensional view, Figures 11 and 12 respectively, augment the mission profile.

Mission segmentation facilitates analysis by providing smaller and more convenient units for study. The mission profile was divided into units of time for developing timelines and workloads. It was also divided into eight phases of flight to provide manageable elements to examine in the analysis, Figure 13.

In a sense, the composite mission for which the flight profile was drawn is unrealistic. The aircraft was launched to provide close air support. Ordinarily, the ordnance loading mix for such a mission would not permit the additional engagements imposed on this particular flight. The purpose of this approach to the problem is to create a worst case situation that is designed to subject the pilot to the most severe operational environment possible in terms of workload and endurance.

3. MISSION SCENARIO

The mission scenario, presented in the following paragraphs, describes the mission profile in an expanded form through narration.

In the ready room, Alpha Leader and his flight are in an alert status for a close air support mission. Checking the weather in the vicinity of potential battle areas, Alpha Leader finds that there is a deteriorating trend. At present, there is heavy cloud cover from approximately 2,000 feet above the terrain up to 27,000 feet. Briefings are received of the general battle situation, communication frequencies, ordnance loads, and the specific areas in which enemy surface-to-air missile (SAM) firings can be expected. Alpha Flight is assigned to Forward Air Controller (FAC) Charlie. After a quick run to the plane, the engines are started and all systems are checked for a go status. Calling the remainder of the flight, Alpha

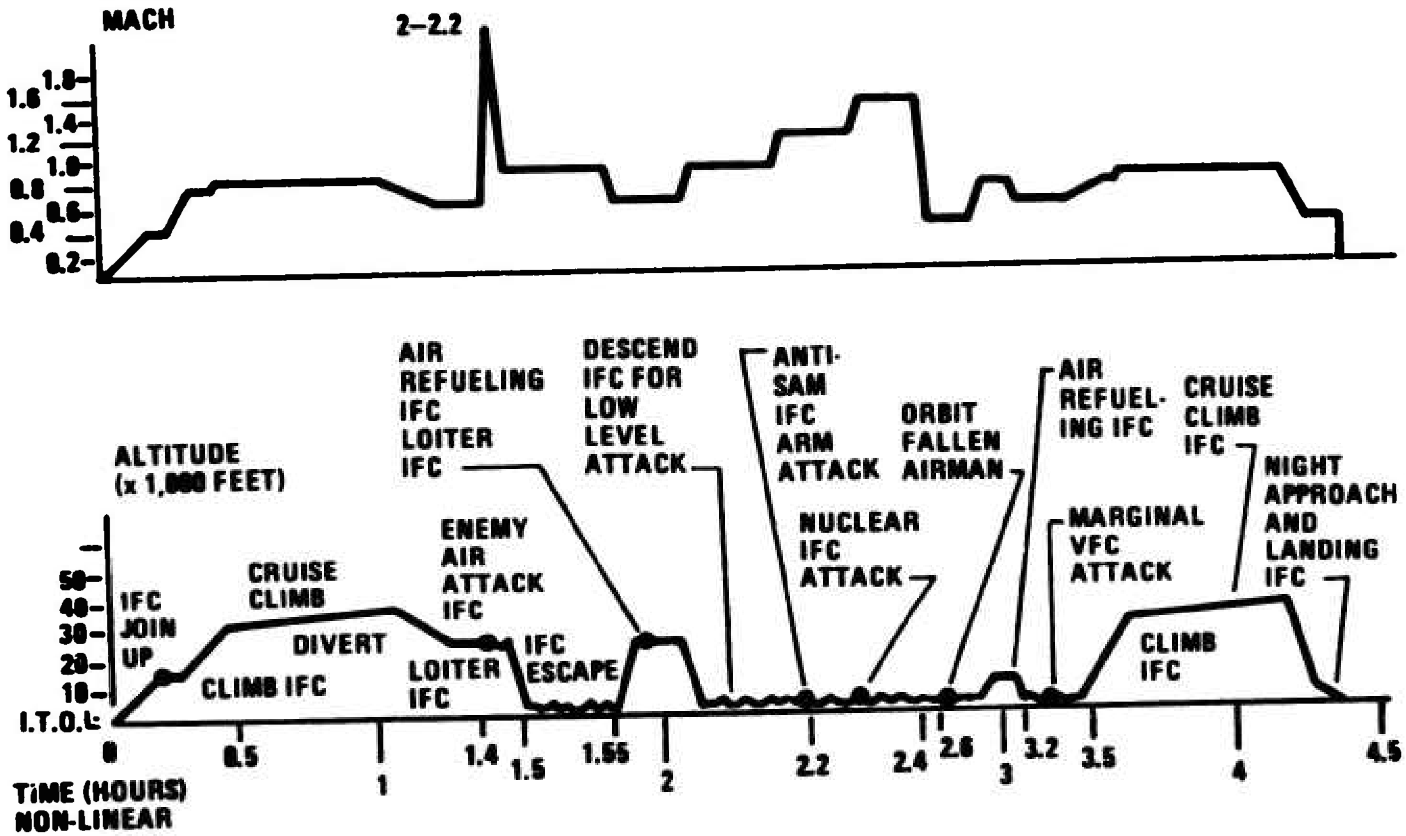


Figure 10. Mission Profile

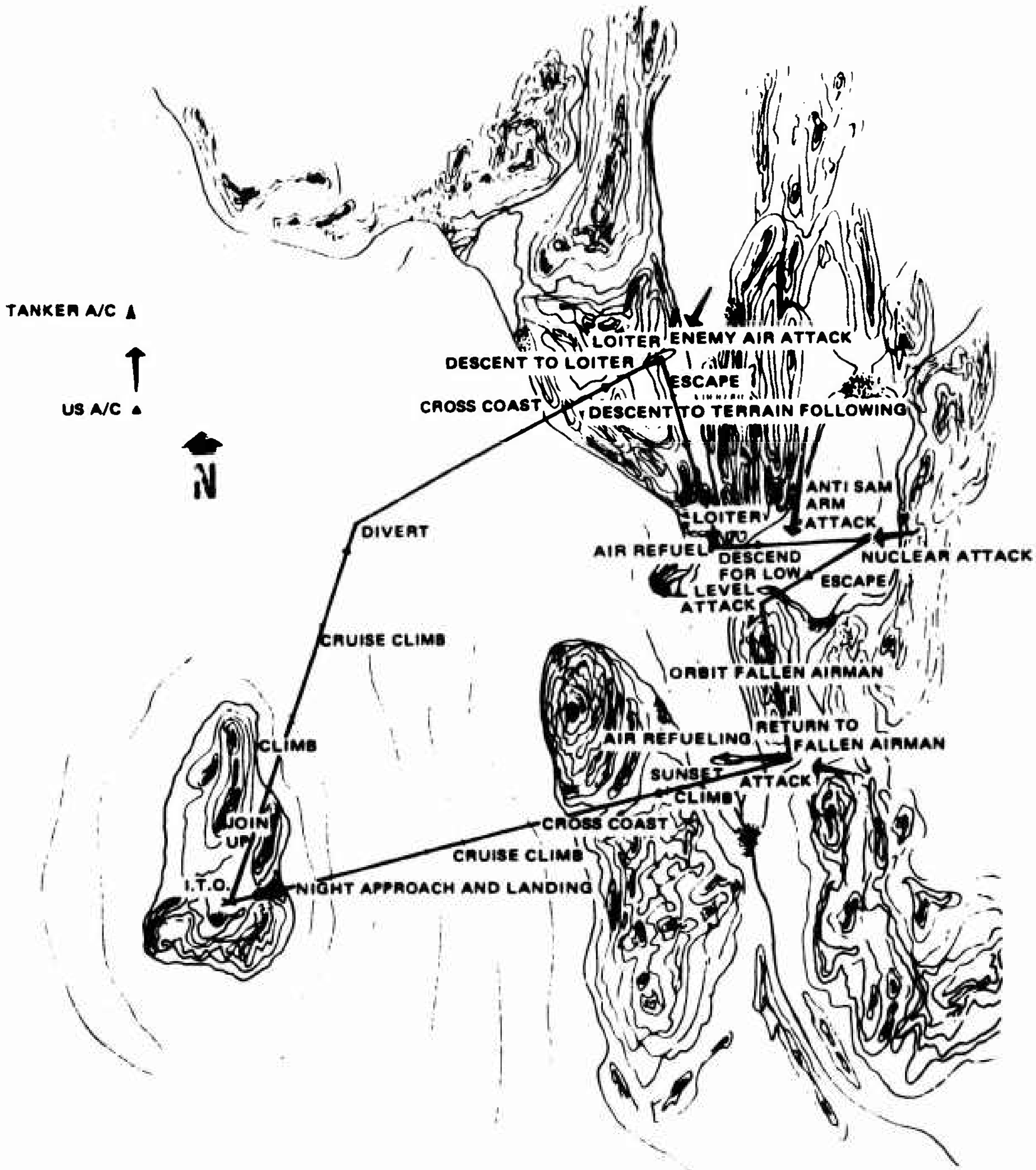


Figure 11. Mission Profile

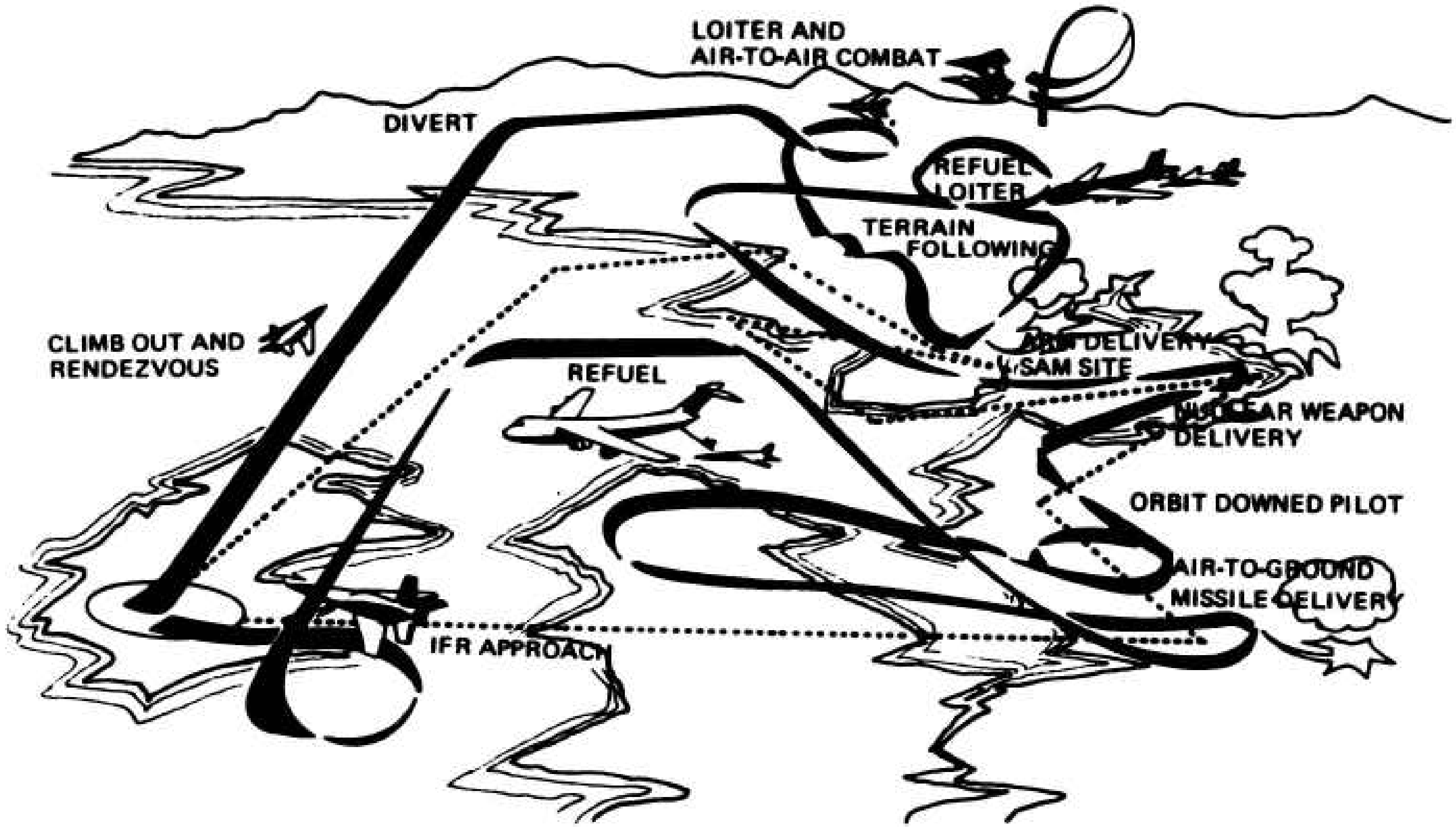
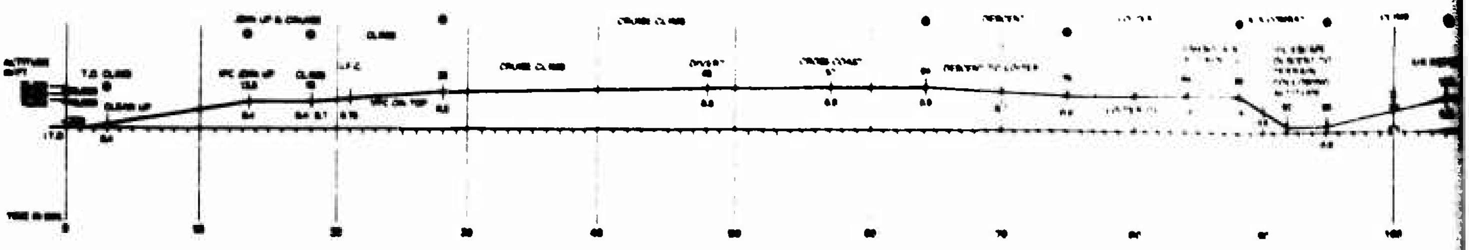
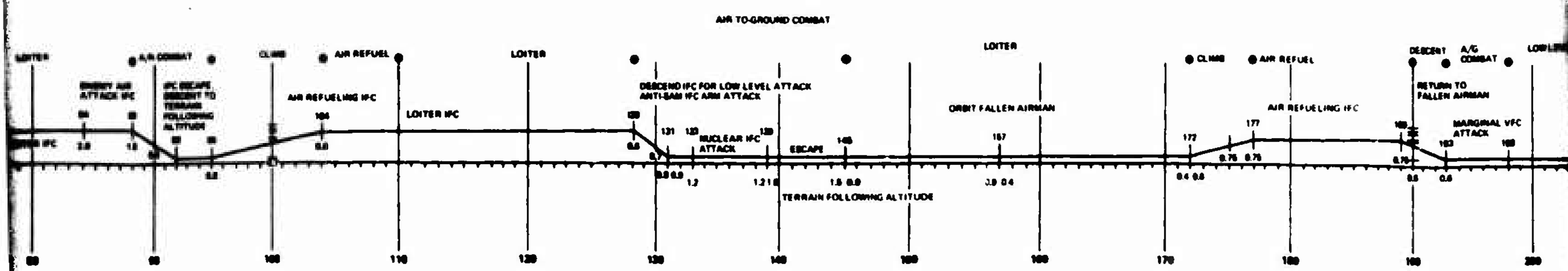


Figure 12. Mission Plot



ALT	S.L.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MACH	0.2	0.4	0.4	0.7	0.75	0.8	0.8	0.8	[illegible]	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TIME	3	[illegible]	4.5	3	7	7.0	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N.M./MIN	2.2	4.25	4.2	7.3	7.7	7.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DIST	6.6	[illegible]	[illegible]	21.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL TO TURN	[illegible]						[illegible]				[illegible]	[illegible]	[illegible]					



[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	S.L.	S.L.	S.L.	S.L.	S.L.	[illegible]	[illegible]	[illegible]	S.L.	S.L.	S.L.
2.0	1.5	[illegible]	0.9	0.8	0.7	0.8	0.7	[illegible]	[illegible]	1.2	1.8	0.8	0.4	0.8	0.75	0.75	[illegible]	[illegible]	[illegible]
4	2	2	3	5	4	24	2	1	2	6	6	12	15	3	2	13	3	5	0
30.1	16.4	[illegible]	[illegible]	8.5	7.2	[illegible]	7.3	[illegible]	[illegible]	13.2	16.8	[illegible]	4.4	6.5	8.1	8.0	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	20.4	42.5	[illegible]	ORBIT	14.6	[illegible]	[illegible]	76.2	[illegible]	110.8	ORBIT	10.5	[illegible]	ORBIT	RETURN PILOT	TO DOWNED & ATTACK	[illegible]
[illegible]	152.1					0	122.3				[illegible]	110.8	0	36.7		0	35.7		

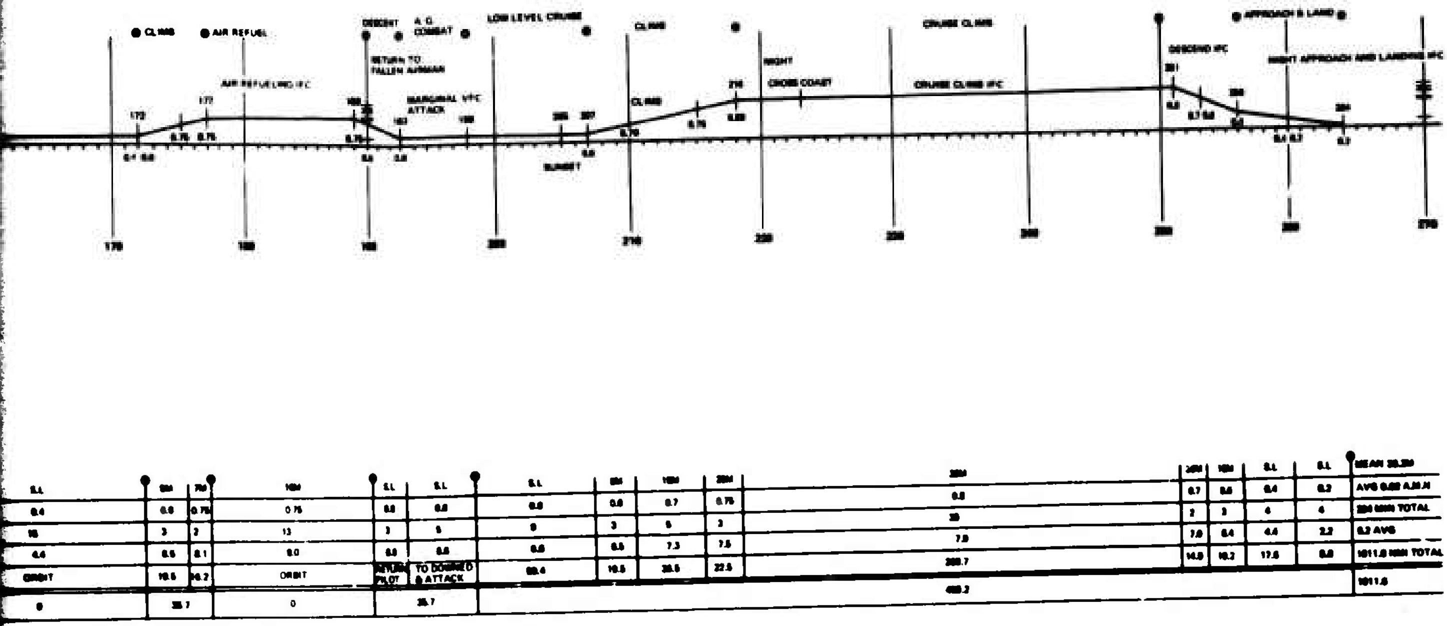


Figure 13. Mission Profile

Leader determines that all are OK. Ground Control is contacted and an immediate clearance is obtained to taxi to runway 31. As the end of runway 31 is approached, Alpha Leader calls the tower to obtain clearance for takeoff. The tower has previously cleared all planes from the landing approach and departure zones. Alpha Leader and his flight are cleared for individual take-offs with 15-second intervals. Cleaning up the airplane, Alpha Leader contacts Departure Control for a steer to the rendezvous point. Clearance and steers are received. When rendezvous employing station-keeping techniques is completed, a handoff from the Departure Control to Battle Area Controller is made. Departing the coast, visual flight conditions are encountered just before reaching cruise altitude.

Cruise climbing toward the target area, control is passed to FAC Charlie. Charlie briefs the flight on the situation, but does not assign specific targets because the situation is too fluid. Before reaching the assigned loiter area, Charlie reports that the situation is taken care of by ground action, and he releases Alpha Flight. Battle Area Control is contacted for a new assignment. The flight is diverted to a loiter area for FAC Pine Tree. Passing the coastline, the flight arrives in the vicinity of Pine Tree. The flight drops to optimum loiter altitude and a briefing is received. Targets are not assigned at this time, but Pine Tree confirms that Alpha Flight will be needed soon.

A warning of enemy fighters heading for the loiter area is received from Battle Area Control. Alpha Leader acknowledges receipt of the warning and, in anticipation of an air-to-air combat situation, selects and arms a weapon. Heading and altitude commands are received from Battle Area Control that should provide minimum intercept probability. On-board warning devices indicate a tracking condition and countermeasures are employed successfully countering the attack. As the enemy passes Alpha Leader, he determines that he is in a position to attack and releases the selected air-to-air weapon. The area controller indicates that another enemy plane is maneuvering into an attack position. Alpha Leader elects to head for the ground and employ instrument flight terrain following tactics to avoid further attack. Battle Area Control soon advises that the threat is over and that Alpha Flight should return to loiter. Because of the unscheduled diversion to a new target area and the air-to-air combat episode, Alpha Flight air refuels while loitering.

During loiter, FAC Pine Tree briefs Alpha Leader on the target and battle situation. The target is a large

group of airborne troop-carrying vehicles reported by a picket craft to be moving across an expansive bay. A tactical nuclear weapon attack is authorized.

The attack path is guarded by a SAM site. Hoping to escape detection by employing terrain following, Alpha Leader descends to minimum instrument flight terrain following altitude. Arming an anti-radar missile (ARM), he continues to his assigned target on autopilot. On-board warning devices indicate sporadic tracking by SAM radar. Alpha Leader "pops up" and with an offset tactical maneuver he negates the SAM threat with the ARM weapon and returns to terrain following.

Doglegging as he proceeds to the target area, he elects to use electronic coordinates for fire control purposes, in lieu of line-of-sight sensors, to preclude further detection. Friendly forces in the area are advised of the zero time and coordinates of the impending nuclear attack. Alpha Leader configures for nuclear effects protection. Battle Area Control inserts the first arming vote into the tactical nuclear weapon and, nearing the Initial Point, Alpha Leader inserts the second arming vote. The weapon delivery and airplane escape maneuvers are executed on autopilot, and the target is destroyed.

Alpha Leader calls his flight to determine their status. Alpha Red is having propulsion trouble due to ground fire over enemy territory in a nearby sector. The condition deteriorates rapidly and Alpha Red elects to eject. Alpha Leader calls the remainder of the flight and sends them to the loiter area to await further assignment. Then he monitors Alpha Red's landing. The automatic beacon included in the escape package will only be used intermittently since it might pinpoint Alpha Red's position for enemy forces known to be in the vicinity. Alpha Leader calls Battle Area Control and requests that a rescue team be sent to pick up Alpha Red. The rescue craft are about 20 minutes away. Alpha Leader must stay on the scene to give the rescue craft an exact position and to afford protection for the downed pilot. Anticipating the need for refueling, Battle Area Control has dispatched a tanker to refuel Alpha Leader. At dusk, refueling in instrument flight conditions is completed about the same time as the rescue craft arrives. It is directed to Alpha Red's position.

Sweeping the area with the on-board sensors, the displays show a vehicle to be making its way toward Alpha Red. Nearing Alpha Red's position, Alpha Leader drops his plane below the cloud cover but cannot visually sight the vehicle hidden by the foliage. He assumes the vehicle to

be armored and selects and arms an appropriate weapon. Using the provided sensors and displays, Alpha Leader locates his target. One mile from the target in the diminishing light, he makes a final visual check that confirms the target to be an armored personnel vehicle. The selected weapon is dispensed using the armament control system in conjunction with the on-board sensors.

With the enemy threat removed, Alpha Leader climbs to altitude to make the flight back to base; he crosses the coastline relaxed, hungry, and thirsty. He takes a candy bar from the sustenance compartment and drinks some water. Otherwise, the night instrument cruise climb back home is uneventful. All systems are checked and a report is made to the home base maintenance group so that they will have everything ready for his return.

As the base is neared, control is passed from Battle Area Control to the Approach Controller. Contact is made and an approach is established. Since the beginning of the mission, the weather conditions at the base have gotten worse. A heavy but patchy ground fog obscuring the runway necessitates an instrument landing. As the airplane is lined up on the landing beam, Alpha Leader is switched over to the Final Controller for landing. Upon landing, Alpha Leader switches to Ground Control for taxi instructions to the assigned revetment. As the plane is parked and before the engines are shut down, maintenance personnel, who have been awaiting the arrival of Alpha Leader, make a final check of all systems.

4. AIRCRAFT SYSTEM CONCEPTS

To ensure currency with the latest and projected technology in the related fields, fact-finding visits were conducted both to military and industrial facilities. A summary of these visits is given in Appendix II. Only successfully demonstrated equipment, at least at a laboratory level, was considered as a candidate component for the advanced tactical fighter. Boeing fighter studies, Boeing consultants, and interviews with military personnel with recent operational experience (Wild Weasel) were sources of additional information.

The systems described are presented in the present tense--as though the system existed in actual hardware form. Equipment identified in contemporary terminology is done so in the generic sense only. The intent in these cases is to describe the function a system performs rather than existing 1970 hardware.

a. Aircraft Description and Performance

Figure ? shows the study airplane. Its maximum gross weight is approximately 52,000 pounds, which includes a 12,000-pound ordnance payload and 1,000 rounds of 20mm ammunition in addition to fuel. At a weight of 41,000 pounds, the design load factor is 8.0. Surface loading varies from approximately 120 pounds per square foot with wings out to 100 pounds per square foot with wings in at combat weight. Using engines strengthened for operations to Mach 1.5 at low altitude, the thrust-to-weight ratio is 1.4 at a combat weight of 35,000 pounds.

Sustained operations of Mach 1.2 in afterburner at sea level may be expected with a dash capability of Mach 1.5. At optimum altitude, speed performance is Mach 1.6 at military power, Mach 2.3 sustained, and Mach (dash) 2.5 with a variable inlet or Mach (dash) 2.4 with a fixed inlet. Dash speeds are temperature limited and may be held for about 1 minute. At military thrust, a speed of Mach 0.98 may be achieved at sea level carrying a full ordnance load.

Since the mission places primary emphasis on air-to-ground weapon delivery, the airplane's engines and inlets are optimized for low-altitude high-speed operation. Although the mission requires effective weapon delivery under instrument flight conditions, certain aspects of the stipulated close-support mission (e.g., troop strafing, etc.) require visual capability for the delivery of ordnance. Accordingly, the airplane concept is configured to provide the pilot with downward vision over-the-nose that will meet all mil lead requirements for the firing of guns and the release of stores (before target passes from view under the nose). A depression angle of 15° from the horizontal provides this capability using any existing ordnance except certain high-drag bombs that have some release parameters requiring larger angles. The over-the-nose vision provided also permits 4° descent path landing approaches to forward area bare bases without having the aircraft's nose obscuring direct view of the runway. Advanced base operations require relatively steep visual and instrument approaches to a landing. A vision plot from the eye reference point is presented in Figure 14.

The requirement for an automatic variable-sweep wing was dictated by the desire to achieve optimum lift-to-drag ratios for low-altitude attack operations over a broad velocity spectrum. A manual control option enables the pilot to improve airplane ride quality in turbulent air. In addition, the variable sweep wing

ATOFF'S EQUAL AREA PROJECTION OF THE SPHERE
radius of projected sphere equals one decimeter

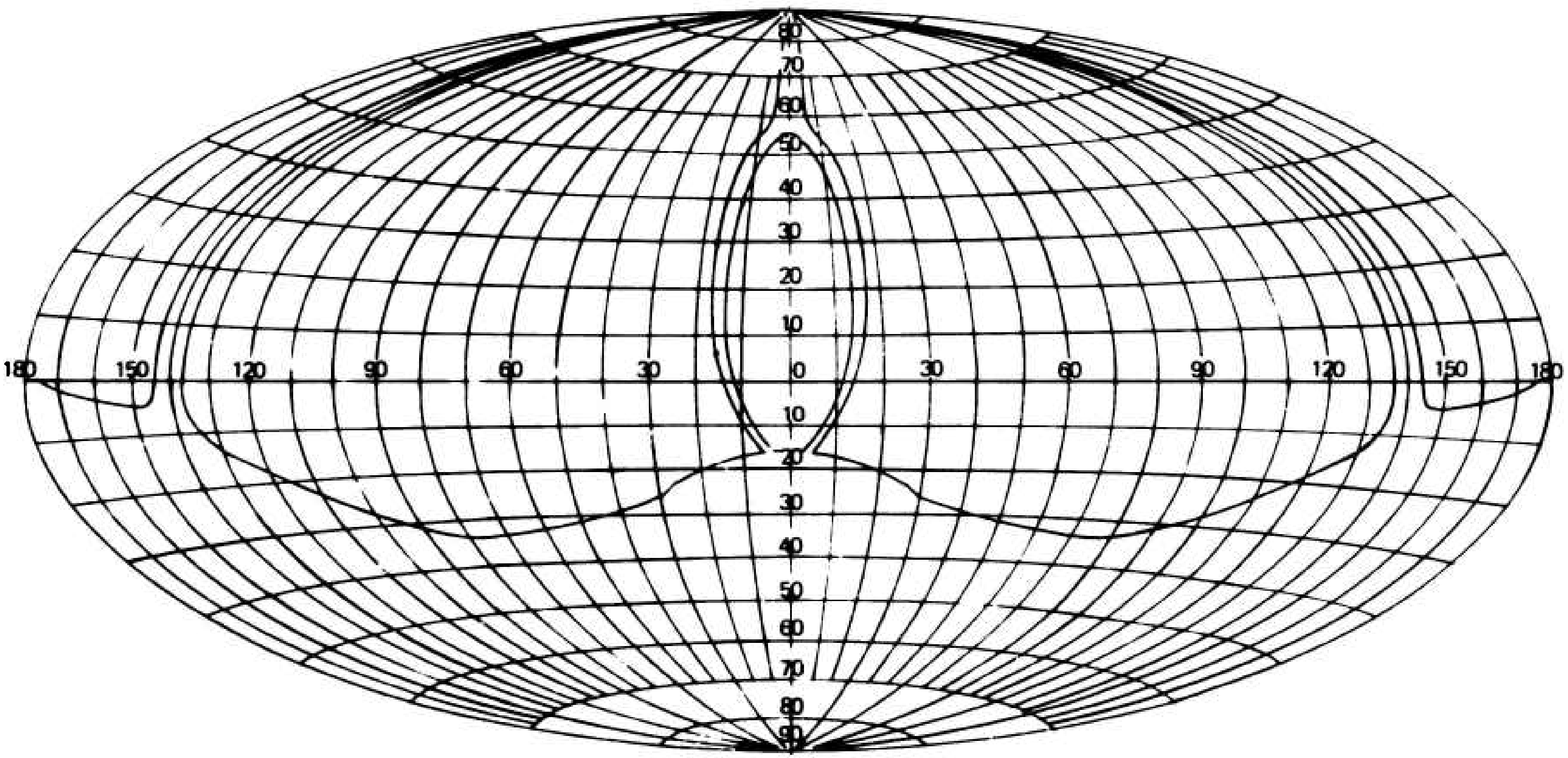


Figure 14. Vision Plot

aircraft provides superior short-field takeoff performance over that of a comparable fixed-wing aircraft.

b. Aircraft Systems

The systems that comprise the overall tactical fighter's weapon system are identified in the Interface Diagram (located in pocket inside back cover). Each system was examined in every flight segment to determine the impact of the failure, first on safety of flight and then on mission completion.

Although the systems were ranked according to probability of failure, it was decided to assume battle damage and examine all critical systems in every segment of the mission.

The requirement for a sophisticated failure monitor and control system (FMACS) resulted from the failure ranking study, Appendix I. Data acquired for this study showed that less than one-fourth of the listed aircraft failures are detected in flight. Although some failures may be maintenance induced, indications were that a better failure detection system was needed; consequently, the FMACS was conceived.

The following design concepts include a description of the contingency operation provisions added to the system as a result of degraded mode considerations.

(1) Flight Control

The primary control surfaces of the aircraft provide flight control along all three planes of operation. The primary control surfaces include movable horizontal stabilizers, rudders, and flaperons incorporating artificial feel devices. Continuous automatic damping about the three axes of the airplane is provided. A self-adaptive gain system is incorporated to optimize aircraft response. The spectrum of conditions to which the self-adaptive gain system is tuned is modified by the mode of flight selected. Control harmonization (responses to the controls with respect to the other controls) is also affected by the mode of flight selected. Adverse yaw compensation provides signals to the rudder to reduce control cross-coupling effects.

The movable horizontal stabilizers, controlling pitch, are augmented by redundant thrust vector controls. A high degree of maneuverability is achieved by optimizing the coupled action of the two pitch control devices.

Yaw control is achieved by symmetrical displacement of the twin rudders. Roll control is accomplished by spoilers and stabilons. In the forward angles of wing sweep, spoilers and flaperons serve as roll controllers.

High-lift devices include leading-edge slats and slotted flaps. Direct lift control is accomplished with the flaperons. The slats are stressed for use during maneuvers involving high dynamic loadings.

Spoilers and thrust reversers are intended for both landing and in-flight use.

The survivable flight control system combines fly-by-wire aircraft control with duplex integrated hydraulic servo-actuator packages installed at each flight control surface location.

Each package contains a dual hydraulic actuator, two independent hydraulic power sources, and a quadruple signal path control unit. Each hydraulic power source is supplied electrical power from separate power sources; if electrical distribution malfunction occurs, power may be supplied through the auto bus tie, the Auxiliary Power Unit (APU), or a DC source. Reliability provided by this arrangement is considered equal to that of current mechanical/hydraulic systems.

Malfunction and warning of failure of any power or signal channel are presented to the crew as a caution warning of a single channel failure. Warning is presented by a flashing master caution light and a warning readout on the MPD. A single channel failure is not cause for an abort. If two channels fail, either power or control, the warning changes to a no-go situation prior to bomb safe line or point of no return. Warning would be presented by a flashing master caution voice warning and a readout on the MPD; the mission should be aborted. If this type failure occurs after passing the bomb safe line, decision to abort is at pilot's discretion.

(2) Propulsion

The aircraft is powered by two low bypass turbofan engines equipped with afterburners. Interchangeable engines, mounted side by side, may be started by the on-board APU. The engines are strengthened for dynamic pressure loadings through Mach 1.5 at sea level. Bleed air from either operating engine provides the means for starting the other.

(3) Fuel

The aircraft fuel system consists of self-sealing wing and fuselage tanks filled with polyurethane to reduce sloshing. Internal fuel capacity is 10,000 pounds. An additional 5,000 pounds of fuel may be carried in inflatable auxiliary fuel tanks.

An inert gas or a fuel spray enrichening blanket is used to minimize fire and explosion hazard during combat. External fuel is carried in inflatable auxiliary tanks or may be carried in drop tanks. The system is designed so that all fuselage stored fuel may be drawn off by the engine-driven pumps if boost pumps fail.

The normal position of the cg control switch on the fuel system control panel permits the central computer complex (CCC) to control the distribution and transfer of fuel as required to maintain the aircraft cg within specified limits for any selected flight mode. This position affords the CCC flexibility in fuel management. If degradation occurs, it will automatically select alternate methods of controlling the cg. At some level of degradation, the pilot manually performs these functions. A few controls are provided to give the pilot sufficient cg control for safe flight.

Ground refuel-defuel is accomplished through a single point refueling receptacle. A fuel/refuel control panel is located adjacent to the receptacle. When activated, this panel governs system control and shutoff valves to permit selective fueling of any or all tanks in the aircraft without external power. This panel displays fuel quantity as a digital readout. Each tank may be refueled independently with gravity fillers.

Fuel is distributed in fuselage tanks in deference to cg requirements. High-performance boost pumps permit rapid fuel transfer for in-flight and single-point refueling as well as cg control. Provisions for gravity fueling are included. Fuel dump from takeoff to landing weight may be accomplished within 5 minutes after initiation of the operation.

The aircraft can be refueled in flight from a tanker aircraft equipped with either a drogue or flying boom. A common point for drogue or boom refueling is located in the pilot's forward field of view.

(4) Electrical

The prime electrical power supply is an engine-driven variable-speed generator (alternator), which uses a hybrid arrangement with a solid-state DC link converter to provide controlled frequency requried for limited on-board equipment. The AC generator produces 115-volt, three-phase power supply. Additional on-board power sources include an APU and a battery.

External and internal lights are provided.

The exterior lights include: anti-collision/fuselage, position, formation, air refueling, landing, and taxi.

Anti-collision/fuselage lights are located on the top and underside of the fuselage. When extended, the anti-collision lights flash red; when retracted, the fuselage lights are white.

The position lights consist of the standard configuration; a white light on the tail, a green light on the right wing, and a red light on the left wing. The wing position lights on the wings' gloves illuminate to conform with the specifications for position lights when the wings are swept.

The formation lights correspond in color to their respective position lights. They are located on the upper and lower surfaces of each wing tip. Those lights situated forward and aft on each side of the fuselage are amber.

Air refueling lights are mounted in the air refueling receptacle for flying-boom night in-flight refueling operations. Since the system is also compatible with probe and drogue refueling, forward lighting is provided for drogue illumination.

Landing and taxi lights are located on the nose landing gear. The lights are extinguished when the gear is retracted.

(5) Landing Gear

The retractable, tricycle landing gear includes fairing doors that are sequenced closed in both the retracted and extended positions, since the aircraft will operate from unprepared fields. Brakes with anti-skid provisions are included on all three wheels. Collapsible, high-inflation tires inflate rapidly as the landing gear extends.

(6) Life Support

The upward firing crew escape module encompasses the pressurized cockpit and provides for safe descent with an escape envelope extending from zero altitude and zero speed through maximum operating altitudes and maximum dynamic loadings. Automatic parachute deployment occurs at altitudes less than 15,000 feet or as set to meet operational needs. Chaff dispensing and emergency beacon transmission capabilities are provided and may be deselected if desired.

The environmental control system provides the functions of cockpit air conditioning and pressurization, transparent area clearance, avionic equipment cooling, and anti-icing of flight surfaces and of sensors as required. Emergency operation provisions are also included.

Bleed air from the engines is manifolded and passed through a precooler and an air cycle cooling system. Cooling air for the precooler is provided by the avionics compartment cooling fan during ground operation and ram air during flight. The cooling air for the air cycle cooling system is provided by an integral turbine-driven fan drawing either compartment or ram air. Turbine discharge air, controlled to as low as 35°F, is passed through a water separator before entering the cockpit. Special design considerations are given to maintaining a fog-/moisture-free cockpit and minimizing hot or cold air drafts.

The environmental control system (ECS) maintains cockpit temperatures between +60°F and +80°F during all flight operations and below 100°F for ground operations on a MIL-STD-210A hot day. Relative humidity less than 70 percent is maintained during flight operation. Provisions for a USAF standard anti-G suit are provided for high altitude flight conditions.

An on-board, regenerative oxygen system is provided for life support. This device uses bleed air from the engine compressor as its source to separate nitrogen and other gases and to produce a continuous flow of pure oxygen to the pilot during aircraft operation. A storage tank provides an additional source of oxygen.

(7) Miscellaneous Subsystems

In addition to the flight controls, individual hydraulic units serve the wing sweep, high-lift devices, speed brakes, thrust vector control, gun chargers,

landing gear, nose-wheel steering, and landing gear brake systems. As in the flight control system, the units are compact, self-contained, electric-driven hydraulic pumps with an integral reservoir. Vulnerability to enemy firepower is reduced significantly by using dispersed redundant units.

The pneumatic system includes tire inflation, fuel tank pressurization, engine start, engine door operations, and engine anti-icing.

An electrically heated wind screen is used as an anti-icing device and provides protective resiliency against bird impact.

A liquid rain removal system that cleans bug and salt spray deposits from the windshield is included.

5. AVIONICS SYSTEM CONCEPTS

The avionics concept described herein uses the M-5 version of the F-15 avionics as a point for departure. Innovative concepts and technological improvements are discussed. Some functions performed are called out by names that are familiar today; however, this does not imply that the equipment performing the function today will still be in use in 1980.

This avionics description and the display and control descriptions following apply primarily to the most sophisticated cockpit. Avionics specifications that go beyond the conceptual descriptions and into precise capabilities and requirements are not included as they do not influence cockpit design directly.

The section proceeds from descriptions of general concepts and equipment that affect many parts of the avionic subsystem to the specific system components including the displays and controls.

a. Computer

Successful advanced tactical aircraft system operation depends heavily on the continued availability of computing power. This dependency exists even when battle damage of component failure occurs. This section of the report describes specific computing hardware and software requirements implied by such a dependency.

Weapon systems of the 1960's that use computer systems have computing hardware and software that are relatively vulnerable to computing hardware failures. Only a limited class of failures can be overcome by developing the system's failure response in advance. Most failures generally result in the complete loss of computing power, an intolerable situation for an advanced tactical fighter system. To achieve the high degree of continued computing power availability necessary, the advanced tactical fighter system has a computer system that can:

- Detect more than one failure.
- Automatically establish a circumvention or recovery procedure to eliminate the effect of failures.
- Provide a residual level of computing power that fully meets minimum essential computing requirements for the tactical fighter system.

The computer system can also handle specialized computing associated with the operation of synthetic aperture radars, pattern matching associated with automatic target recognition, and signature analysis of complex wave forms. In addition, the computer system is supplemented with a digital data transmission system to permit communication with the rest of the avionics equipment within the advanced tactical aircraft system. The digital data transmission system can operate in spite of component failure or battle damage.

Complementary to the essential system capabilities described above is the software system. This system includes an executive program that is responsible for the operational management of the computing system while simultaneously checking for loss of computing power. If such a loss occurs, the executive controls the circumvention procedures necessary to overcome its effects. Application programs carry out the many functional tasks required by the advanced tactical fighter system. Supporting software is also present in such areas a self-test and

diagnostic procedures. This support software checks for failure of any computing element or other avionics systems able to communicate (through the digital data transmission system) failure data to the central computer. Appropriate evaluation and circumvention procedures are initiated when a failure is detected. Lastly, ground support programs exist to assist in the design, construction, maintenance, and documentation of the operational computer programs. These programs include compilers, assemblers, file programs, etc.

The computing system for the advanced tactical fighter system can execute some one million operations per second, using about 131,000 locations of memory to store programs and constants. The minimum level of computing power to which the system can degrade is approximately one-half the nominal computer size; that is, 500,000 operations per second and 64,000 memory locations.

The computer system for the advanced tactical fighter weapon system is configured as a multiple computer system to provide continued computing power in spite of battle damage or component failure. This multiple computer configuration is organized into a multi-processor configuration. The multi-processor system automatically assigns computing tasks to separate elements of the computer system. Additionally, it automatically reconfigures the computer system in response to the detection of the loss of individual computing elements. The multi-processor configuration has certain specialized hardware features as well as an advanced and sophisticated software executive system to carry out automatic tasking and automatic reconfiguration responsibility. In addition, the advanced weapon system computer has excess (redundant) computing elements to allow the system to reconfigure in response to the loss of failed elements, and still provide the indicated minimum computing capability. Approximately four 500,000-operations-per-second processor units are available to ensure availability of the minimum computing power requirement of 500,000 operations per second. The memory system is divided into modules of some 16,000 locations per module. Timeline memory modules are installed in the computer system to ensure continued availability of at least four modules. A proportionally high level of redundancy is carried out for the input/output areas of the computer system, as well as the digital data transmission subsystem. Therefore, if the entire system is operative when a mission starts and the mission lasts approximately 10 hours, the computing system for the advanced tactical fighter weapon system will probably fail to provide the necessary minimum computing power only once in one million mission hours. It should be indicated that

the cost in volume, weight, power, and dollars for the indicated basic and redundant computing elements is quite reasonable; i.e., only 2 cubic feet in volume are required to house the entire computer system.

Installation of the computing hardware is only part of the task of integrating a computer system into the advanced tactical fighter weapon system. Developing the necessary 100,000 to 200,000 statement program required by the advanced tactical fighter system is a very significant and difficult task. Software is a high leverage, long lead time element for any system using a stored program digital computer. The long lead time associated with acquiring operational software is directly attributable to the difficulties in defining functions to be carried out in each part of the avionics system and, as a result, the functions to be carried out in computer hardware and software. Functional definition, analysis, logic flow generation, design, development, and checkout and test of software require a large integrated effort.

Special-purpose processors are provided to support avionics elements such as the fixed-plane or conformal design multimode phased array radars. These special-purpose processors compute beam pointing and return signal vectors even while the advanced tactical fighter system is performing very rapid maneuvers. The computations involve resolution of aircraft inertial attitude into the specific coordinates of the conformal or fixed-plane radar system. Similar special-purpose processors are used to solve signature analysis problems associated with electronic warfare and communications.

The computer performs computation, processing, memory, and time standardization for the total airplane system. The services include but are not limited to:

- Autopilot
- Stability Augmentation
- Air Data
- Primary and Secondary Navigation
- Weapon Delivery
- Energy Management
- Fuel Management
- Maintenance and Failure Detection and Processing

- Countermeasures Programming
- Anti-Skid
- Environmental Control
- Auto Throttle
- Phased Array Antenna Control
- Automatic Target Acquisition and Identification

Multiplexing is a method for transferring data items from one place to another using a single conductor. With the digitization of the computer inputs at the source instead of at the computer and the capability of using computer outputs directly, it becomes desirable to use multiplexing to interface system components.

Multiplexing greatly simplifies interconnecting hardware and system maintenance by eliminating the need for a multitude of wires, connectors, and junction boxes. System modifications to add new functions or to change functions can be accomplished without extensive rewiring; however, the computer programming will need changing. Multiplexing makes practical the wraparound cockpit, in which the instrument panel is structurally secured to the hinged canopy, by reducing the number of signal cables to a minimum of three plus the redundant power wiring. Redundant wiring can be routed into the canopy area at different entry points to minimize the possibility of battle damage.

Multiplexing mechanization is the subject of a complete study. A Boeing document (Ref. 1) discusses many possible multiplexing alternatives and recommends a modulation technique. Two multiplexing methods might be used profitably in this tactical fighter; one for the normal digital interfaces and one for the displays. For the displays, a frequency division multiplex scheme, similar to a cable TV system, could supply signals to the raster-type displays. Thus each display would become a TV receiver with all the symbology developed in the computer.

The most promising digital technique appears to be pulse code modulation using split-phase, bipolar modulation or phase-reversal modulation for the digital interface. However, considering the very short cable runs that would be used in the tactical fighter, possibly the internal modulation technique used by most computers, non-return-to-zero polar modulation, should be considered. The relative advantages and disadvantages of these and other techniques are discussed at length in Ref. 1.

To be effective in reducing interface complexity, multiplexing requires the standardization of the multiplexed signals to a single format. All sensors, controls, displays, and transducers should be designed to produce or accept the common standardized format. Standardization can be on an airplane basis, on an Air Force basis, or on a joint service basis. The degree of standardization depends on the desired degree of equipment interchangeability that can be accomplished without using adapter units.

b. System Data Inputs

Four methods for feeding data into the system are suggested for use in the tactical fighter. These are a tape cassette, a data link, a keyboard, and human voice. Each method has a distinct use.

The tape cassette is used to program the mission into the computer. The program includes waypoint, checkpoint, target, and destination locations and navigation and communication frequencies. This tape is produced by a ground-based computer and carried on-board by the pilot. A read-only capability is employed in the airplane to preclude the possibility of inadvertent computer program loss.

Data link input is used to reprogram the flight from either a ground-based operation such as an air operations center, a forward air controller, or an airborne warning and control center. One other use may be to control the airplane from the ground during low visibility landings. When the pilot is physically incapacitated, the aircraft may be controlled remotely. Data link is considered to be an adjunct of the communications capability.

The basic keyboard, Figure 15, consists of an 8-key master keyboard select panel and 38 multifunction keys. Dedicated keys are included to perform the functions of clear, modify, display, enter, backspace, and space. The keyboard is energized when there is power on the system.

A pre-entry readout is provided for verification of keyed instructions before entry into the system.

The function of each key is:

CLEAR--Clears entry up to time of enter. Clears display when properly keyed and cleared.

MODIFY--Modifies information already in storage. Allows type over, thus replacing stored data.

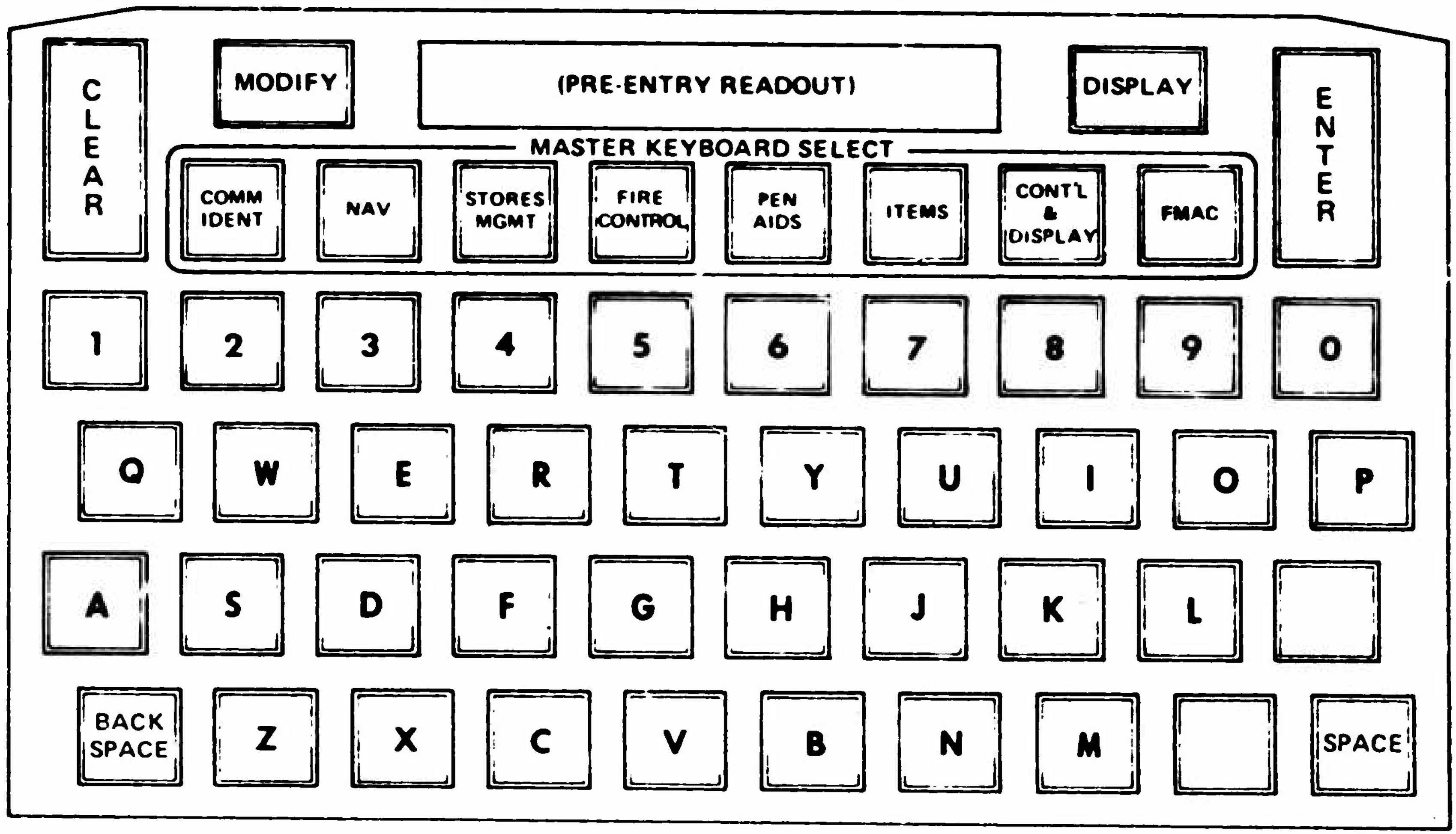


Figure 15. Basic Integrated Keyboard

PRE-ENTRY READOUT WINDOW - Presents data as selected on keyboard before entry. If an entry error is made and the computer rejects information, selected data will pulse until correct entry is made.

DISPLAY - Displays total message to be entered on MPD #5, or displays any recalled message without modifying data.

ENTRY - Enters data into system and reverts keyboard to basic legend.

MASTER KEYBOARD SELECT - Contains 8 function keys used to call up selected functions.

FUNCTION KEYS - Thirty-eight multifunction keys with up to 48 separate functions per key are provided. A set of functions is called up for each master keyboard select key depressed.

BACK SPACE - Clears a single keyboard entry such as an error in frequency. Back space if repeated depressed will operate similarly to a typewriter backspace key providing the capability of correcting single digit on unit entries.

Keyboard/voice entry is selected on the mission control panel and keyboard entry is selected on the integrated keyboard to type in a computer program. When the switch is activated, a modified teletype keyboard legend (Figure 15) is presented and programming may be done by typing in abbreviated plain language.

To allow the pilot to command certain operational changes during critical flight phases, without requiring him to use the hands, the human voice can be used to call out frequency changes for the communication and navigation equipment. A Boeing-developed voice recognition device, based on International Business Machine patents, is in laboratory operation. It recognizes the sequential usage of key command words. The voice command entry technique allows the pilot to enter changes into the system without using the keyboard. It uses a faculty that has not been used formerly except for voice communications.

c. Failure Monitor and Control System (FMACS)

The FMACS for advanced tactical aircraft is more than the traditionally conceived on-board test and checkout system; it is a programmed control system that performs many airborne and ground-oriented functions.

While airborne, these functions include system status reporting to the pilot and data linked to a remote monitor, warning of flight safety conditions, automated corrective actions and display of these actions, and notification of impending failures. On the ground, these functions include automatically controlled preflight, flight/mission readiness, and fault isolation tests.

Integration of these functions under the operational control of FMACS has many advantages. The greatest advantage is that all systems are monitored, the data processed, and the operational modes controlled (either automatically or by the pilot) by one program control.

Figure 16 is a block diagram of the integrated FMACS equipment. The description of FMACS necessarily is a description of the operational role (or functions) of FMACS, and the displays, controls, subsystem monitors, and data processor integrated within the operational role of the FMACS.

While the aircraft is airborne, FMACS primarily reduces and simplifies the pilot's workload if any flight subsystem is in a degraded mode of operation. In many cases, FMACS can completely assume the tasks of restructuring the operational parameters of various systems to eliminate a failed or degraded system's impact on the pilot. In other cases, simple status displays in go, no-go, formats, plus simple corrective directions are displayed automatically to the pilot.

Total aircraft system status is determined and constantly monitored by FMACS. Subsystem status is not displayed to the pilot unless specifically requested through the integrated keyboard control. Only two buttons need to be depressed for the status of any subsystem to be reported on a preselected MPD: first, "test and check" is depressed; then, the name of the desired subsystem is depressed.

When the status of a subsystem changes, the change may or may not be reported automatically to the pilot. Changes in system status that involve either safety of flight or failure in mission performance will be presented to the pilot automatically. Failures affecting flight safety are presented to the pilot automatically through the Master Warning System. Emergency procedures are displayed on the preselected MPD. Failures that may affect mission performance are presented automatically on the MPD. Other failures are not displayed automatically, but are displayed when the pilot requests aircraft status through the integrated keyboard.

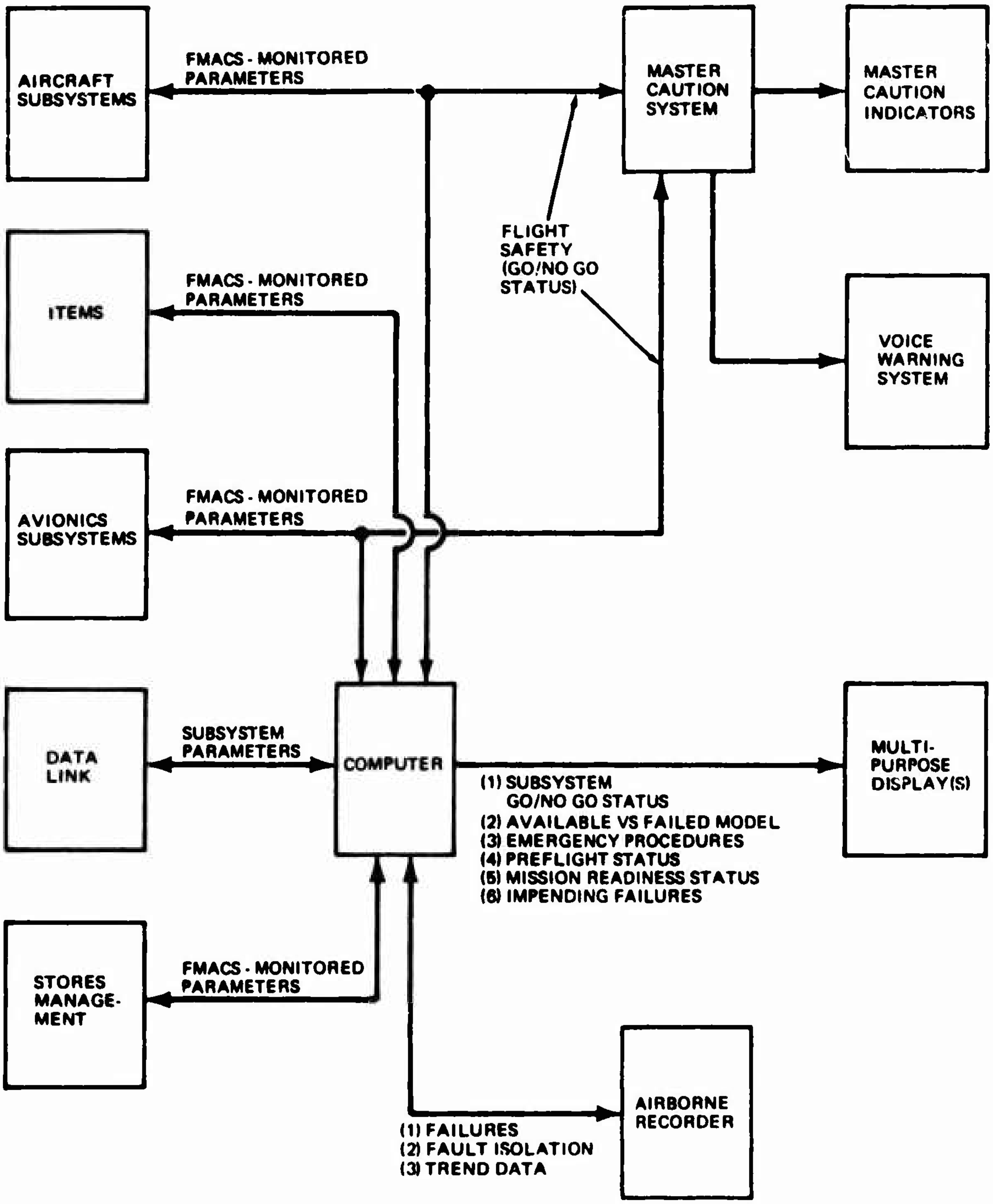


Figure 16. FMACS Control and Display Block Diagram

The total aircraft status in all subsystems will be recorded on a read-write magnetic tape recorder, which under computer control can interface with the data link. Under certain conditions, an external source (i.e., AWACS) can obtain total airplane status automatically via data link and take the necessary corrective action for specific functions. The FMACS will also be capable of determining certain impending failures minutes and possibly hours before a total failure occurs. This feature is limited to only a few, high failure rate or long maintenance time line replaceable units (LRU's), such as hydraulic pumps, APU's, generators, and to some extent, the propulsion system. The principle of detecting impending failures through the content of metallic particles in the oil of a pump, or the noise of a pump, or the amount of flow-by in a hydraulic actuator has been proven for some time. Using these principles on specific pieces of equipment is certainly a feasible feature for the FMACS. In addition, if these impending failures could be mission critical, they will be displayed to the pilot via the MPD's.

While on the ground, the pilot and the line maintenance crews will have the following display formats available:

(1) Preflight Test

This test is done by depressing the FMACS pushbutton (Figure 17). If the airplane is on the ground, the preflight and mission ready pushbuttons will be illuminated. (These functions are inhibited in flight.) Depressing the preflight pushbutton will instruct the computer complex to perform a total system test. If subsystems are not in the proper configuration for test, i.e., power off, specific crew action instructions will be displayed on the MPD's. If a subsystem fails, the computer will automatically isolate and record the results, and display the crew action required to effect the repair on the MPD.

(2) Mission Ready Test

This test is done similarly to the preflight test; the FMACS pushbutton is depressed first, followed by the mission ready pushbutton. This test determines the status of the aircraft subsystems to determine whether those systems necessary for safe takeoff are in their operational mode and are functioning properly. This test is comparable to an automated checklist with pilot information and instructions being displayed on the MPD.

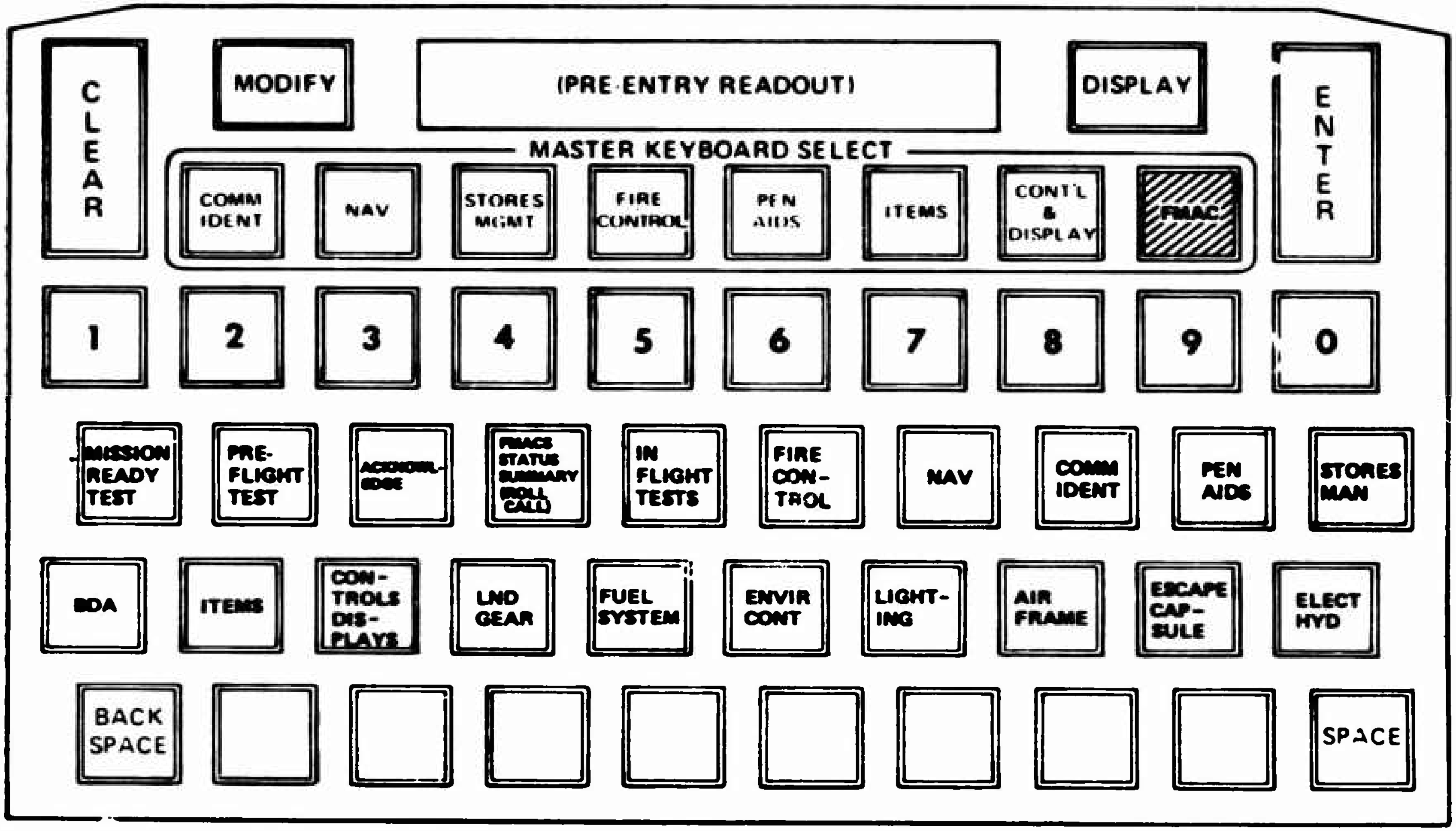


Figure 17. FMACS Control Keyboard

(3) Fault Isolation Tests

Fault isolation tests are conducted both in-flight and on the ground. In-flight fault isolation tests are conducted automatically by the computer complex on a low priority basis; i.e., when the computer workload is down. Fault isolation data will be recorded and transmitted via data link to a remote monitor and to the maintenance center to expedite aircraft repair. On-ground fault isolation will be done automatically as a function of the preflight test. For example, if preflight test results indicate that a system has failed, the computer will enter a fault isolation routine, determine the failed LRU, display the results on an MPD, and record the failed LRU information on tape for subsequent data link transmission to the maintenance center.

(4) Trending (Long Term)

Key parameters indicative of degraded airplane performance are automatically recorded and transmitted to a remote monitor during specific phases of the mission profile on a sample basis. Since this information will be recorded in the same manner as status and fault isolation information, these measurements can also be sent by data link to the maintenance center for further processing to determine scheduled maintenance requirements.

Three groups of displays will be used for FMACS. They are the Master Caution System, flight instruments, and the MPD's.

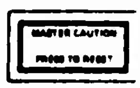
d. Master Caution System

Warning and Caution are presented to the pilot in up to four ways depending on criticality of the failure or malfunction detected. Types of warning are:

Catastrophic - results in loss of system, single or multiple deaths.

Type warning - Tactile - Seat vibration against small of back

Master Caution - Flashing aircraft symbol on VSD/HUD and master caution reset button "ON"



Voice - Plain language of system failure

MPD - Readout of system failed
with emergency procedures

Other tactile warning devices, such as a stick shaker, are installed as required to alert the pilot of an impending unsafe condition.

Critical - Degrades system performance which can result in pilot injury or substantial damage

Type warning - Master Caution - Flashing aircraft symbol on VSD/HUD and master caution reset button 'ON"

Voice - Plain language of system failure

MPD - Readout of system failure with emergency procedures

Marginal - Degrades system performance without major system damage or personnel injury but can be adequately counteracted or controlled

Type warning - Master Caution - Flashing aircraft symbol on VSD/HUD and master caution reset button "ON"

MPD - Readout of system failure with emergency procedures

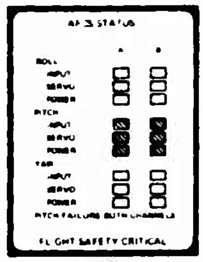
Safe - Does not degrade system and will not produce hazard to crew

Type warning - MPD - Readout of system failure with emergency procedures

Integration of the FMACS with computer direction and recording provides continuous sampling of system status, immediate warning of malfunctions, presentation of programmed emergency procedures, and transmission of system status information to a remote monitor via data link. Automated switching and control provided by the computer complex offers an immediate response to malfunctions where human reaction time precludes a sufficient response. Simultaneous actuation of equipment is also provided where required to safeguard the crew.

(1) System Status

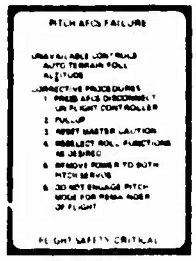
This information is a system-by-system presentation of available versus failed modes of operation. The information provided to the pilot is in go, no-go format and relates to operational modes of the system, not to equipment nomenclature. This display format is controlled through the integrated keyboard; depressing FMACS, the major aircraft and mission systems are listed on the keyboard as shown in Figure 17.



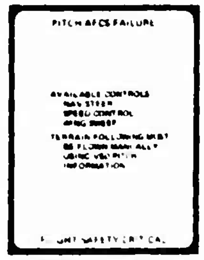
SYSTEM STATUS

(2) Corrective and Degraded Mode Procedures

This information is presented automatically in the same display format as system status when a no-go condition occurs. As the corrective steps are taken, the display format changes as shown.



WARNING & CAUTION



DEGRADED SYSTEM STATUS

(3) Impending Failure

This information is presented automatically when the FMACS detects a failure about to occur.

e. Failure Mode Analysis--Signal Transfer Unit (STU)

The STU is a control unit for mixing and switching composite video to the MPD's. Inputs to the STU include: (1) video signals from the MPD Character Generator, VSD Generator, Horizontal Situation Display (HSD) Generator, TV CAmera, and the radar and FLIR Scan Converter; (2) MPD mode control commands in digital format from the Central Computer Complex; and (3) function control from the MPD controls. Output signals are composite video signals to each of the five MPD units.

The STU is basically a digitally controlled analog switch system. Two redundant logic networks are provided, because failure of this portion would remove computer control from all MPD's. However, the analog switching network that directs the composite video to each MPD is not redundant, because the required data can be switched to a different display when one analog switch fails. The analog switch portion, as well as the switching logic system, is expected to be highly reliable.

f. Scan Converter

The Scan Converter is a solid-state unit with 1024 by 1024 resolution elements. The scan converter is in four sections, each having 512 vertical elements by 512 horizontal elements.

Failure of a single discrete element within the scan converter core does not degrade the performance of the scan converter performance, because loss of individual cells of an actual image is not detectable on a display.

The impact of a massive failure in the write or read logic or the core itself (due to battle damage) can be reduced by redundancy, but this is a costly approach. An alternate and preferred method selected for IIPACS is redundancy provided by dividing the scan converter into four 512 by 512 elements, as described above. All four units operate as one unit with 1024 by 1024 resolution elements until one section becomes unusable. Then the system operates in a degraded 512 by 512 resolution element mode.

An FMACS Control Display Interface diagram is shown on Figure 18.

g. Navigation

The primary function of a navigation system in a tactical combat aircraft is to provide en route navigation and weapon delivery information. The most demanding requirement for en route navigation is to fly to the target and deliver weapons under instrument flight conditions.

The basic navigation system description for the tactical combat aircraft for the 1980 time period includes the total avionics suit available in the aircraft. Detail performance data found in the Navigation Study, Appendix III, is given only for those theater-of-operation systems in the 1980 inventory.

The final navigation system selected from those classes shown in Figure 19 for IIPACS is comprised of three basic subsystems--Doppler, Inertial and Satellite (DIS), augmented with Radar, Data Link and DME position fixing. This system, shown in Figure 20, meets the functional requirements for the tactical mission. Two inertial systems with a backup Heading and Attitude Reference System (HARS) provide the redundancy and reliability required for "fail operational" during critical mission segments. The HARS is a simplified inertial system with a flux valve that provides heading during system initialization and degraded mode operation.

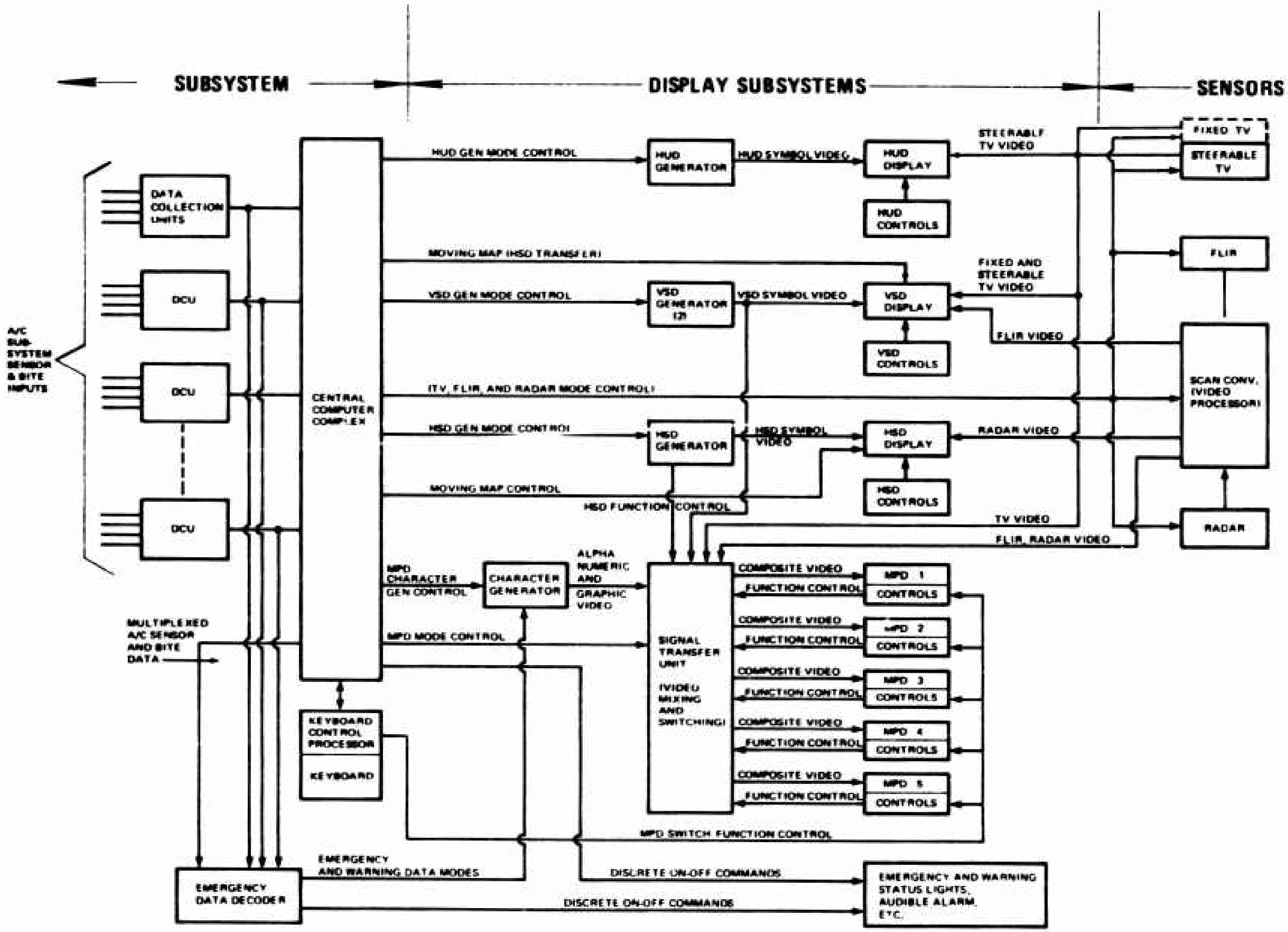
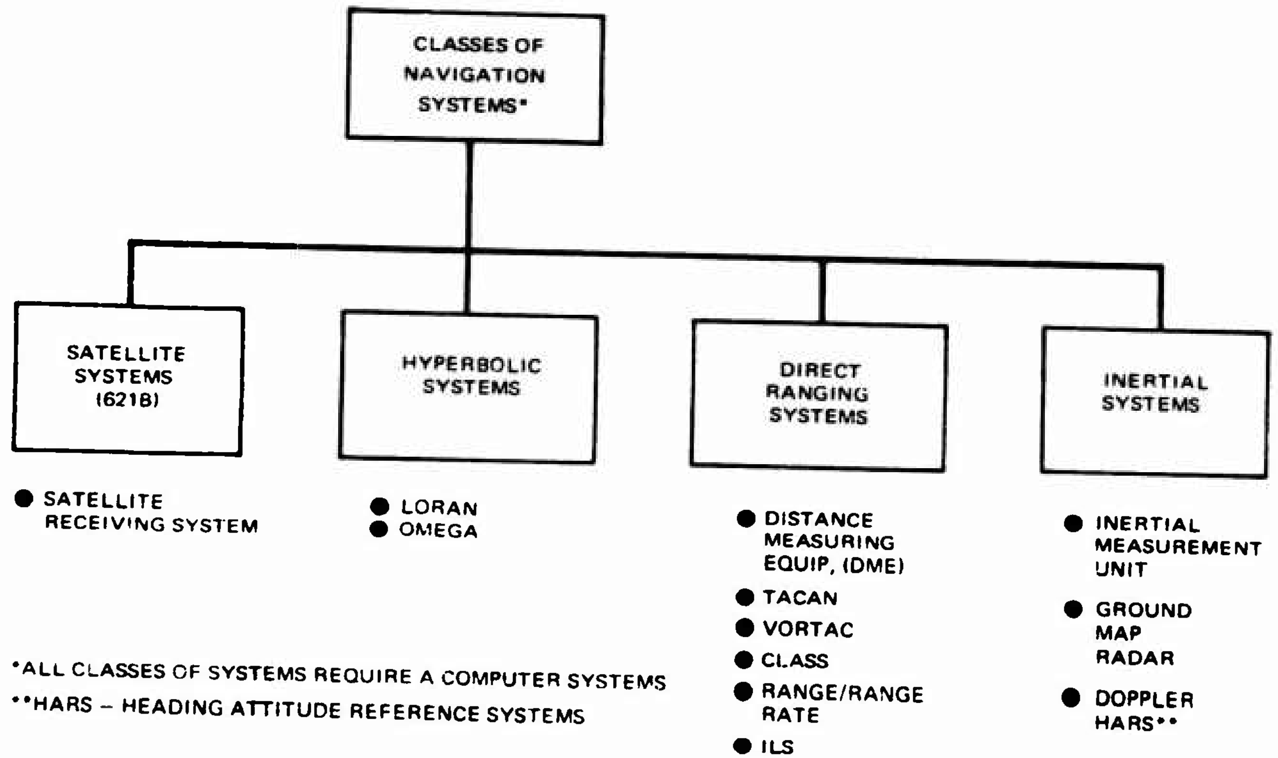


Figure 18. FMACS Control/Display Block Diagram



*ALL CLASSES OF SYSTEMS REQUIRE A COMPUTER SYSTEMS

**HARS – HEADING ATTITUDE REFERENCE SYSTEMS

Figure 19. Classes of Navigation Systems Available for Tactical Combat Aircraft

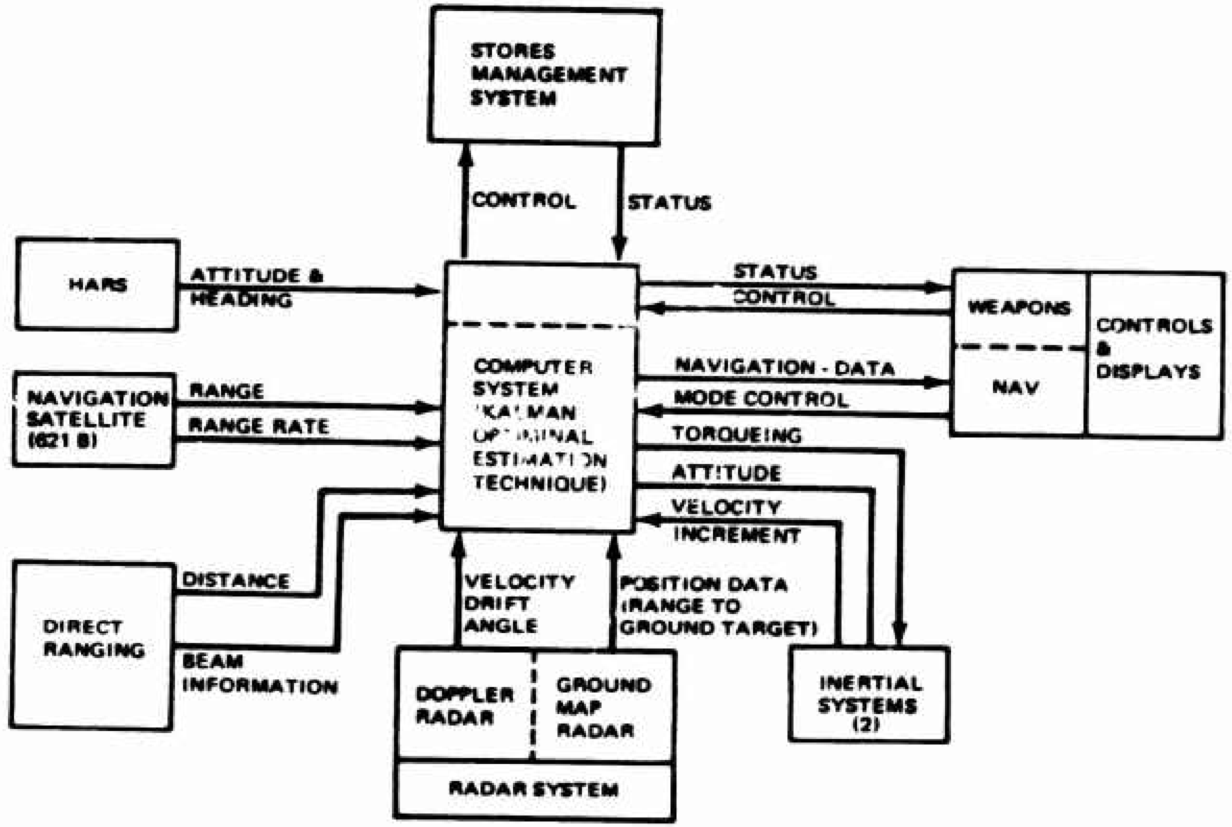


Figure 20. IIPACS Navigation Systems Block and Functional Interface Diagram

Degraded mode options available with the equipment are shown in Figure 21. The selection and switching logic for degraded modes is programmed in the navigation computer. For example, the NAVSAT is the primary source of navigation (position/velocity) data. If NAVSAT fails or if the aircraft moves to a position relative to the satellite cluster such that the NAVSAT data is less accurate than the Doppler-inertial data, the system automatically switches to the Doppler-inertial mode. Thus, the navigation system always operates in the most accurate available mode.

Selection and switching logic for Figure 21 degraded mode option is based on the failure hierarchy and criteria as follows:

(1) NAVSAT is the primary navigation mode and will be used whenever possible.

(2) A NAVSAT failure causes the navigation system to operate in a Doppler-inertial mode augmented by position fixes from the ground map radar. Figure 22 shows the system position error growth.

(3) A ground map radar failure causes the system to fly Doppler-inertial until the direct ranging network comes within line of sight. Thus, the system updates with range/range-rate information,

(4) A Doppler failure in the Doppler-inertial mode causes the system to operate in a free inertial mode with position fixes from the ground map radar. The Schuler oscillation will result in somewhat larger absolute errors, depending on the accuracy of the update. The position updates to the free inertial system should be made about once every 30 minutes. The average position error growth is given in Figure 22.

(5) A Doppler and ground map failure in the Doppler-inertial mode causes the system to operate in the free inertial mode until the direct ranging transponder field comes within view.

(6) A failure of the Doppler radar, ground map radar, and the direct ranging causes the system to operate in the free inertial mode. System position error growth is shown in Figure 23.

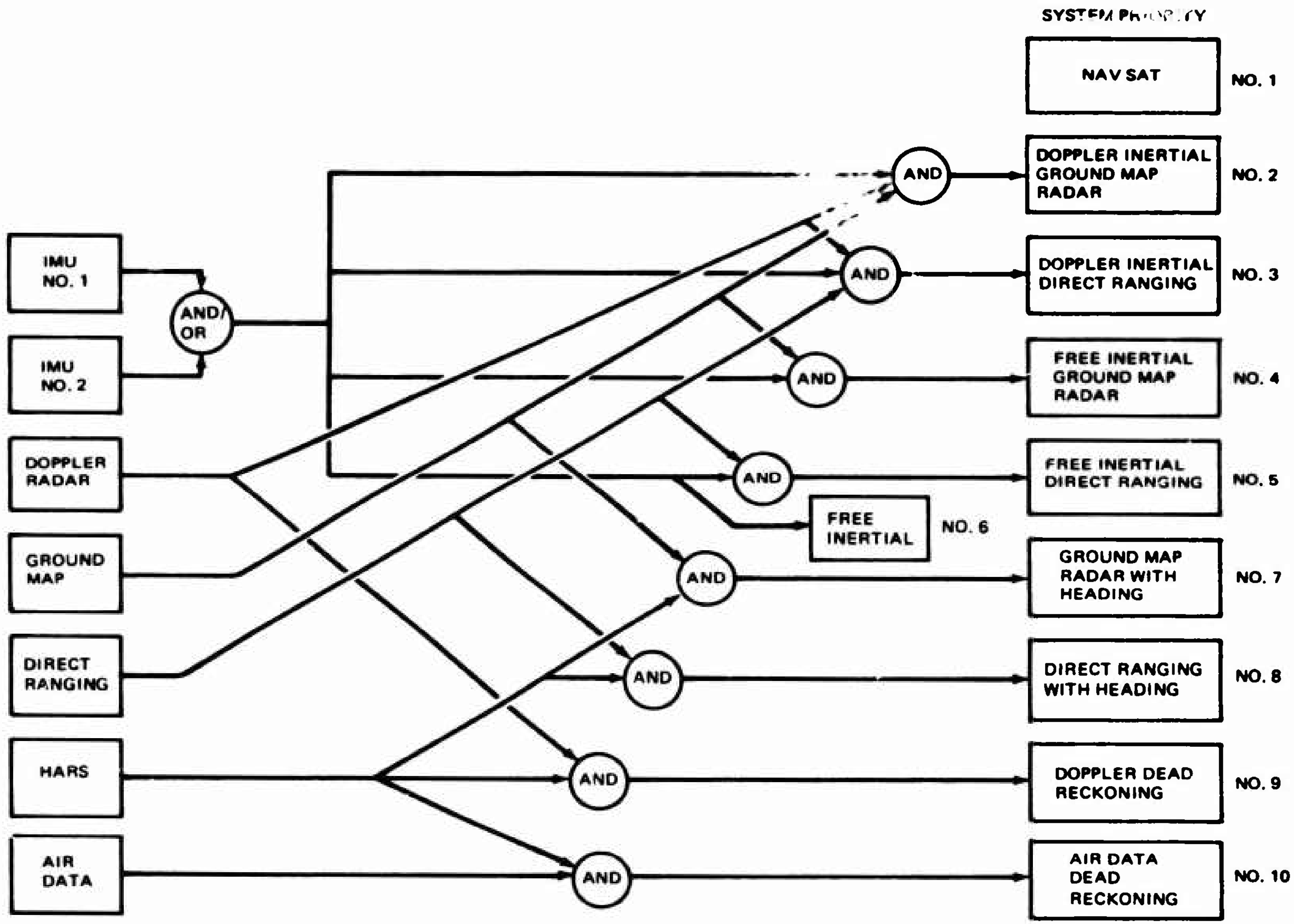


Figure 21. Navigation System Options

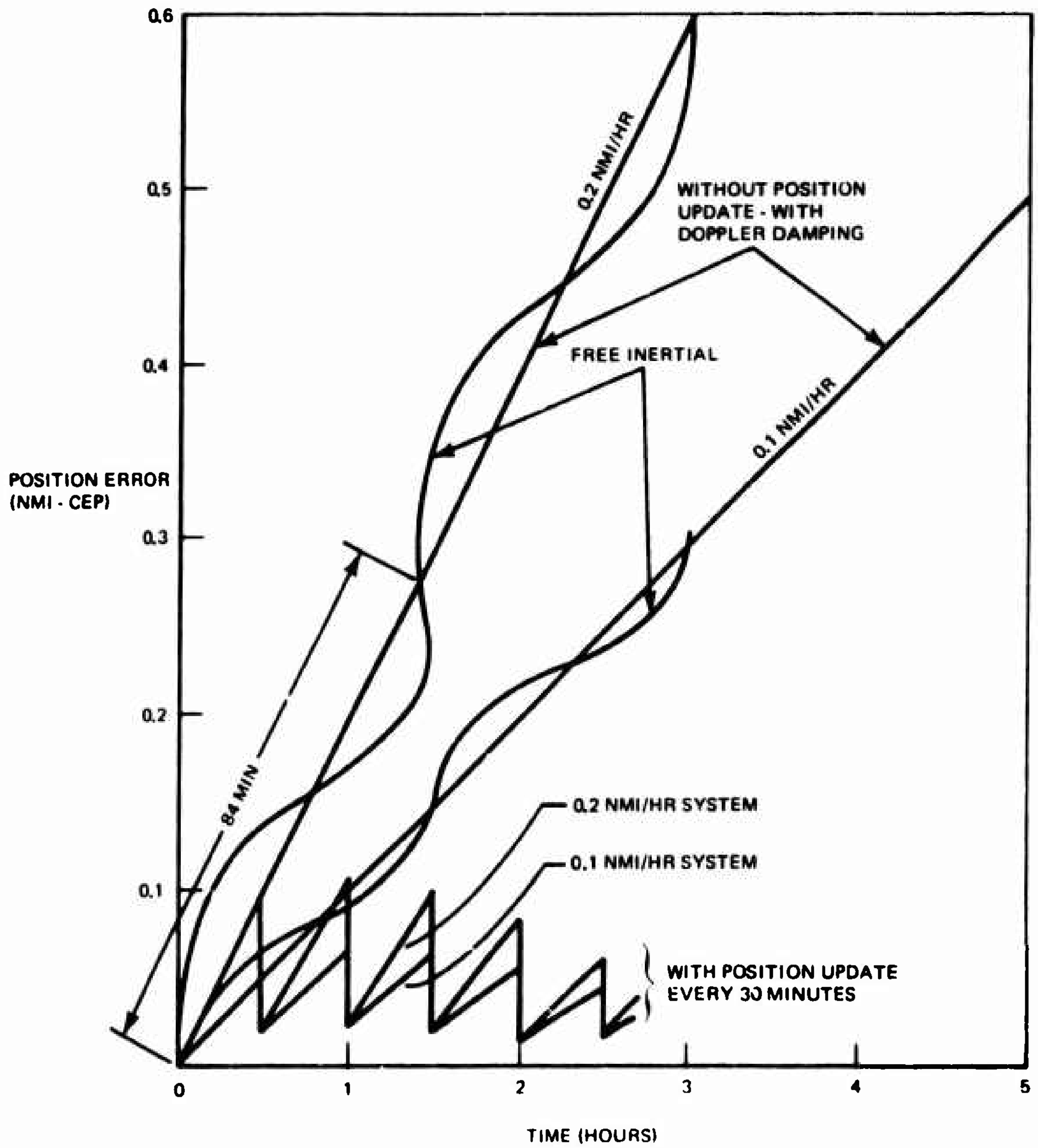


Figure 22. Doppler Inertial Performance With Position Updates

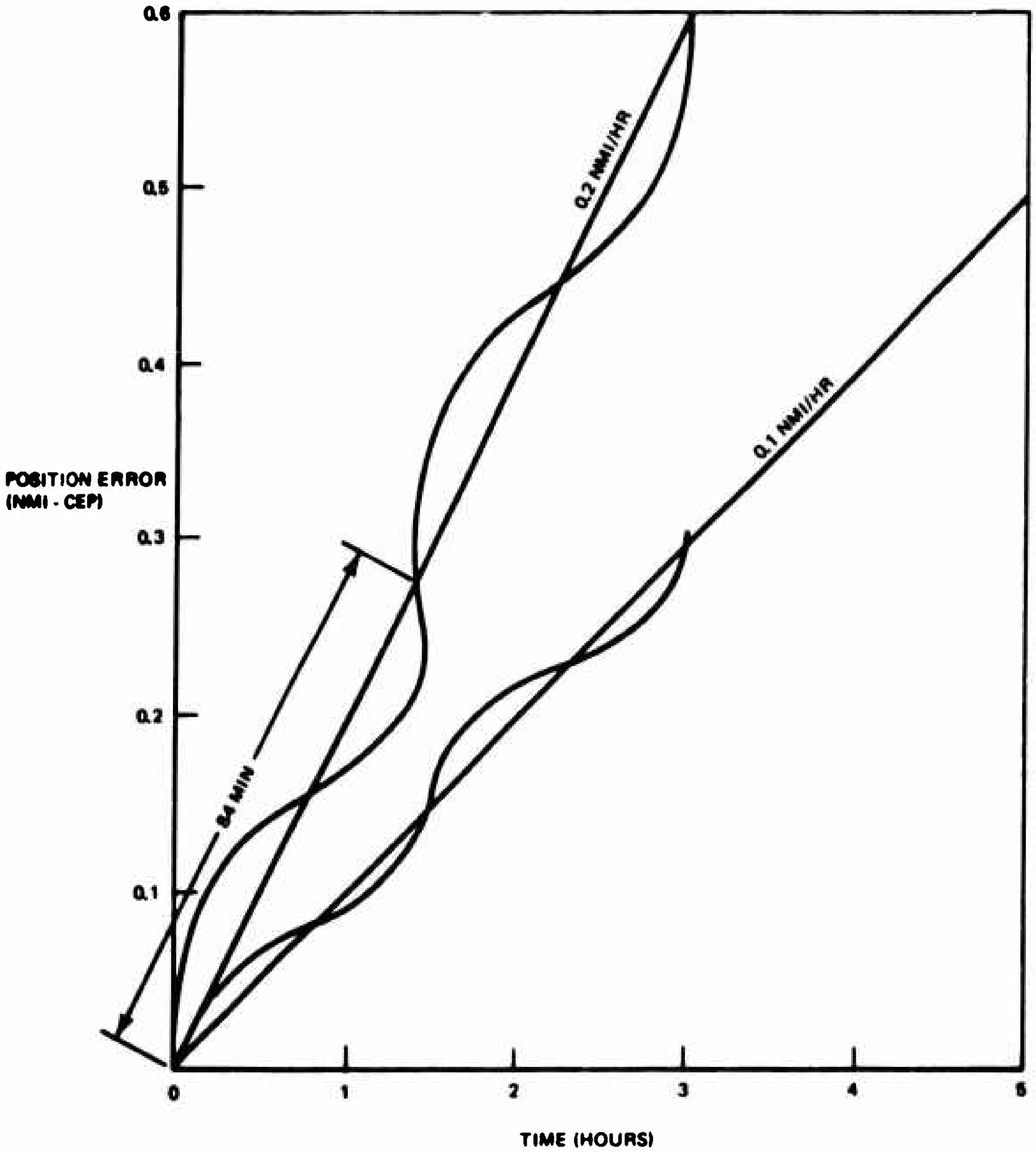


Figure 23. Free Inertial System Performance

(7) Failure of both inertial measurement units and the Doppler causes the system to operate in a backup inertial (HARS) mode with ground map radar updates.

(8) Failure of both inertial measurement units and the ground map radar causes the system to operate in a DME navigation mode with attitude and heading obtained from HARS. As the aircraft flies through the DME field, position coordinates are computed with range/range-rate to the transponders.

(9) Failure of both inertial measurement units, ground map radar, and DME causes the system to operate in a dead reckoning mode. Heading from the HARS is combined with Doppler to compute position of the aircraft. A 5 to 10 nmi per hour CEP growth rate is expected.

(10) Failure of all above sensors simply causes the system to operate in an air data dead reckoning (ADDR) mode. Air speed and heading are used to navigate. This contingency represents a very remote failure pattern due to system redundancy.

h. Antennas

Spherical antenna coverage is needed to operate against threats and targets approaching from different directions. An integrated antenna design concept is desired so that aircraft weight volume, structural shadowing, and interference problems are minimized.

The integrated antenna system consists of multiple phased array systems to satisfy the requirement for spherical coverage. These multifunction arrays use an inertialess, computer-controlled electronic beam steering system to allow coordinated control with minimum reaction time.

Although acceptable designs with either planar or conformal arrays are possible, a conformal array approach with the antennas integrated into the aircraft structure is expected to provide best coverage with minimum aircraft weight and volume penalties.

The arrays are formed to follow airplane contoured sections including those for the nose cone, fuselage sections, and wing/empennage leading edges. Large volumetric coverage is obtained by simultaneously exciting complementary

array sections and by sequential excitation of numbers of adjacent array elements in a given section.

Conformal arrays have primary features common to more conventional antenna systems. The resolution and accuracy are still governed by the projected overall dimensions of the excited array sector (useful antenna area) and the number of active elements in the sector. Specialized antennas are needed for unique CNI and Pen Aids support functions at the lower frequencies.

Array sections are controlled for specific mission functions by preprogramming amplitude and phase changes to different antenna elements. Several specially shaped transmit/receive beams result. Changing amplitude and phase allows these beams to provide limited directional control for sequential or simultaneous multibeam operations. Weak preferred signal reception and/or nulling out of unwanted signals is accomplished by operating in a fully adaptive mode. This provides maximum directional gain to enhance preferred signal return.

The array design facilitates degraded mode operations. The antenna surface areas are vulnerable to damage caused by hostile action. The thinning effect of random hits results in a gradual degradation of array performance.

Single hits with small fragments provide minor damage because the arrays have elements containing individual phase shifters for element to element control. Antenna computer programs are arranged to delete defective or damaged elements; therefore, performance degradation is proportional to the number of elements lost.

Lens arrays, using protected feeds behind the arrays, improve operational performance in degraded modes. Power division, for subarrays is with waveguide and/or stripline feeds. Sectional sources, acting as subarray feeds, and radial waveguide, parallel-plate, distributed feeds tend to localize damage.

i. Communications

Communications, navigation, and identification systems are programmed for integration into one spread-spectrum bandwidth. Each function has a separate address code. Knowledge of the code and compatible equipment allows the users to communicate with each other.

The spread-spectrum technique is designed to reduce vulnerability to enemy jamming and to provide

simultaneous service to many stations or addressees. Satellites are expected to handle hundreds of small mobile terminals with varying power levels without the formal network discipline normally used in satellite communications between large ground terminals.

The greatest advantage in the spread spectrum technique is that it can serve the frequency spectrum by allowing the transmission of many low duty cycle RF users, each with a dedicated frequency channel to operate a single broad channel. Then each user contributes a small amount of noise across the total band. When a high percentage of the total possible users transmit simultaneously, the noise level becomes high enough to cause interference with all the using links. Normally this situation would have an extremely low probability of occurrence.

A secure or private code must be used to provide anti-jam capability. Since each link is spread across the entire available bandwidth, both CW and broadband jamming must overcome the process gain of the spread-spectrum system. Therefore, a great deal of jamming power is required.

The controls necessary to operate a complete spread-spectrum system must include the synchronization and functions of interest, i.e., navigation, local and long range communications, identification, etc., and address codes. Insertion via keyboard of an address code or a code sequence is adequate for full control of the spread-spectrum system.

The communications keyboard, Figure 24, is chosen by activating the C&I key on the master keyboard selector. This illuminates the communications options of the keyboard as shown. The sequence of events to choose a given destination for transmit-receive is:

- Press the PHONE BOOK key. A list of address codes will appear on the classic COMM. MPD. An address may be a ground station, airborne station (AWACS type), or another aircraft. Select a given code from the phone book.

- Press the following keys in sequence: ADDRESS CODE, 1, 2, 3, SEC, VOICE. This will choose address 123 and set up the proper secure voice coding in the spread-spectrum frequency channel. All selections will appear in the verification window before entry.

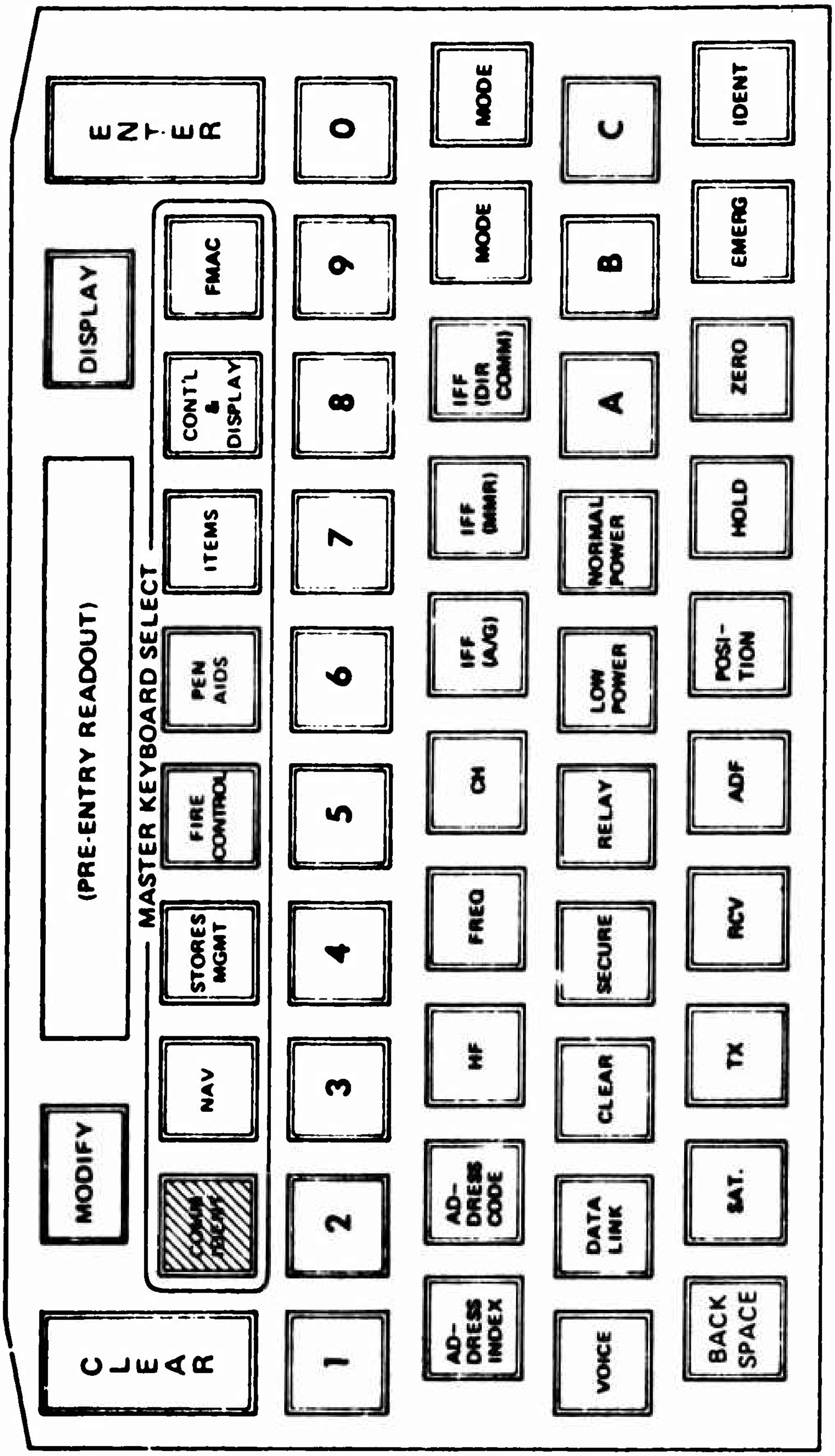


Figure 24. Communication and Identification Keyboard

- Press the ENTER key to enter the data into the system and clear the keyboard for further use. ADDRESS 123 SEC VOICE will appear in the COMM. MPD classic display and in the upper row of indicators at position one on the intercom panel. Communication data for position two and position three would be programmed in a manner similar to that just described above.

j. Identification, Friend or Foe (IFF)

The identification functions of the IIPACS aircraft are accomplished with either of two independent systems. In actual operation, however, they will have a common phased or conformal array antenna system. The IFF systems are described below.

The directional communication IFF system is an integral part of the spread-spectrum communication band. Frequency will be in the SHF band or higher for improved directivity. Spherical (360°) coverage is provided. The antennas are directional during transmit and receive. The system can interrogate another aircraft at a specified bearing when directed by on-board systems through the central computer.

In an operational mission, the directional communication atomic clock is synchronized to a master time source--located at a ground station or airborne command post. When interrogated, the system responds in the same direction as received with the proper code-secure or clear depending on the threat environment. On the other hand, when performing the interrogation, the system directs RF energy at a particular spot in space as determined by the RHAW or MMR through the central computer complex. The IFF system can also transmit in any direction when commanded by the pilot using the computer cursor control (useful during "dogfight" at close ranges).

The multimode radar IFF system is integrated with other MMR functions at the operating radar frequency. Spherical (360°) coverage is provided. Modes 1, 2, 3, 4 A/B and codes are integrated with existing radar pulses with secure message structure contained within each pulse.

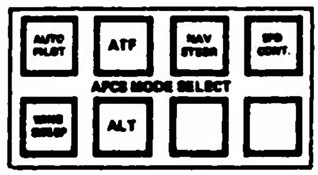
In an operational mission, IFF interrogation may be directed at any target being tracked by the MMR. Normally, all interrogations are performed through instructions from the central computer; however, the pilot may choose to interrogate any particular target being tracked. To perform the interrogation, the pilot designates the

ground or airborne target with the crosshair, obtains a lock-on, and interrogates. Identification is confirmed by appropriate symbology near the radar return, or discrete lights provided on the COMM./IDENT panel.

Justification for two completely independent systems is based on:

- o Inadequacy of existing systems to perform directional IFF functions.
- o Need for redundant systems in a hostile environment to keep from being shot down or mistakenly shooting down a friendly because of a single system failure.
- o Need for 360° coverage at all times with two types of systems, either capable of performing directional identification in a secure mode at reduced power levels.

k. Autopilot and Stability Augmentation



These computational functions are performed in the central computer. The sensors feeding the computations and the computational elements are sufficiently redundant to produce a safe airplane. Stability augmentation cannot be deselected. The various modes for automatic flight are:

- o Control Stick Steer (CSS)
- o Navigation Steer (NAV STEER)
- o Speed Control (SPD CONT)
- o Altitude Hold (ALT)
- o Automatic Terrain Following (ATF)
- o Automatic Wing Sweep (WING SWEEP)

The stability augmentation system (SAS) installed is sufficiently redundant to provide reliability equal to the primary flight control system. The SAS is activated whenever the aircraft is operating with no switching or programming inputs required of the pilot.

Failure warning is provided by the FMACS/CCC in the following manner:

Single channel failure	-	Master caution flashing plus readout on MPD
Dual channel failure	-	Master caution flashing, voice warning plus readout on MPD

If two or more channels of the SAS are inoperative, the pilot is advised to select a flight regime and mode (i.e., cruise) that provides improved stability and to land as soon as practicable.

1. Penetration Aids

Although the tactical fighter's primary mission is to destroy ground targets, self-defense using penetration aids is also necessary. Self-defense options, which include evade, degrade (not to be confused with degraded modes as implied by the nature of this study) and destroy, must be used selectively to minimize primary mission penalties.

Evasion by maneuvering to increase range and decrease closure rate is useful when the threat is not positively identified (friend or foe) or when mission time or distance to target or base is not critical. Use of evasion during terrain following is restricted.

Degradation with ECM, chaff, flares, decoys, etc., is valuable against enemy threats. It is not used when electronic silence is required or where severe mission degradation of friendly forces in the area is possible.

Destruction by counterattack is used with positively identified threats. Counterattacks are a last resort because they compromise the primary mission. Valuable payload would be expended for purposes other than ground target destruction.

The environment for the tactical fighter includes both terminal and indirect threats.

The terminal threats are airborne interceptors (AIs), SAMs, and anti-aircraft artillery (AAA).

Indirect threats are emitters that include the SUAWACS airborne warning and control aircraft, ground control intercept (GCI), height finders, early warning (EW) and acquisition radars as well as communications networks. Reception of signals from these emitters can be considered attack warning.

Both enemy and friendly forces are expected to be operating in the area. When radar or IR signatures, visual

sightings, and/or emissions from an unknown are received, classification as a threat is necessary until true identity becomes known.

Friendly and enemy emitters and signatures must be located to minimize the process of complex identity evaluations and action decisions. Continuous position update is also necessary.

If the decision is to destroy the threat, the threat becomes a target that competes for attention with primary mission-assigned targets. In this case, stores management and penetration aid functions must be worked in concert.

Complete penetration aids functional requirements and typical associated action decisions are shown in Figure 25. Threat concentrations in the vicinity of the tactical fighter will often be too high for manual processing in a one-man aircraft. The action decisions are performed by the central computer complex. Pilot veto is provided.

Countermeasures used on the tactical fighter include automatically programmed transmitters, an IR (tail) jammer, and dispensers for chaff, flares, and expendable jammers. These devices are installed internal to the airplane. The devices are programmed by logic designed into or read into the computer from the cassette. Controls are available for pilot selections. Dispensing rates for chaff and flares other than those preprogrammed may be chosen through the use of the integrated keyboard.

Passive receivers are used to determine the location of enemy emitters. Preprogrammed logic recognizes the threat by its signature. Threat energy sources are primarily in the S- through K-bands and in the IR region. Threat information is displayed to the pilot and used to activate the active countermeasures. The pilot's battle situation display is shown on one of the MPD's and/or on the HSD. Pilot emergency warning of an approaching terminal threat (such as missile launch) is provided by a voice warning that informs him of the clock sector and whether the enemy is high, level, or low.

Electronic jamming transmitters are packaged in interchangeable modules to allow use of various types of ECMs, depending on the enemy capability in the mission area. These transmitters are controlled by the computer from signature characteristics and field strength and from pre-established threat priority logic.

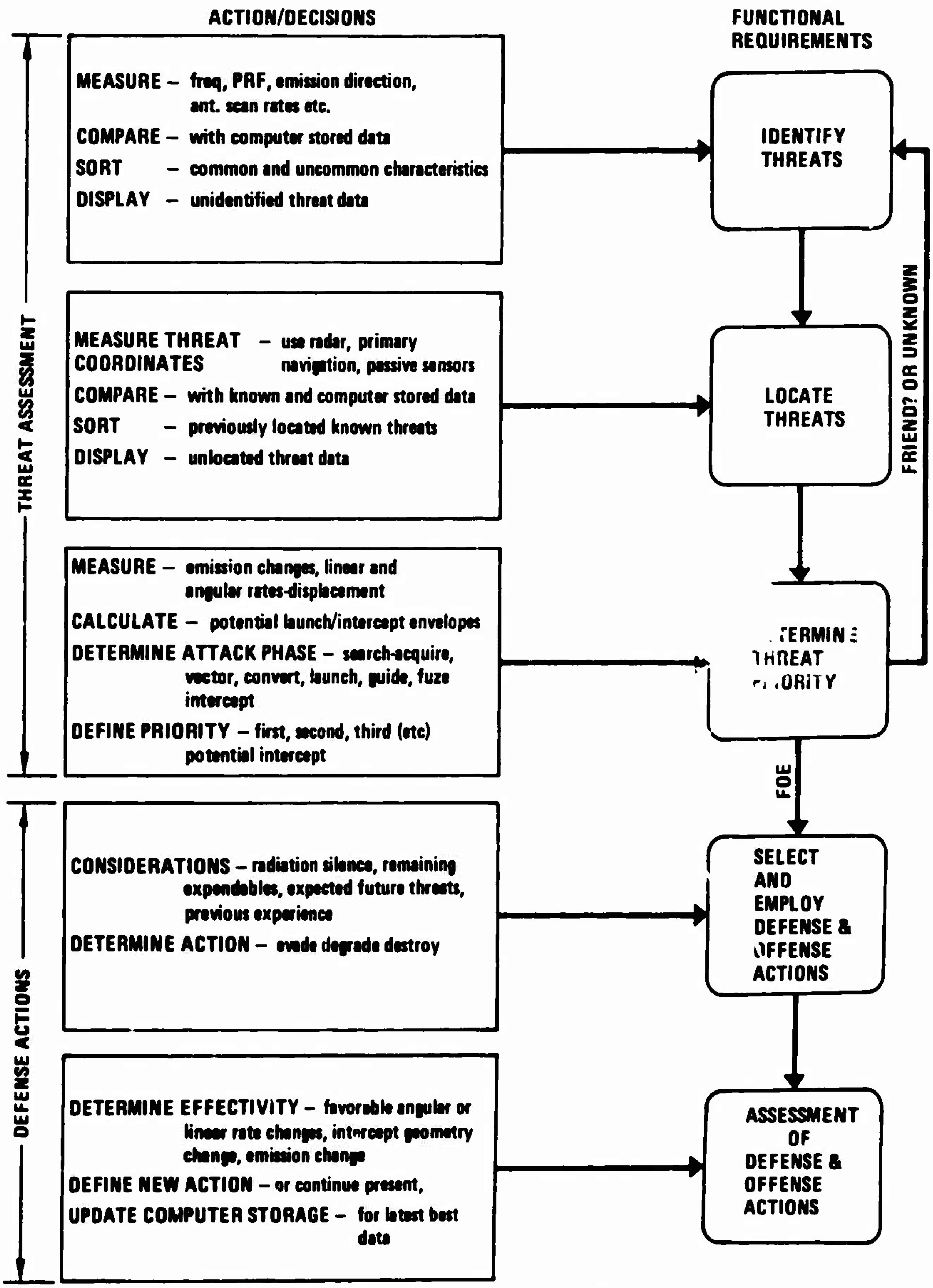


Figure 25. Penetration Aids - Actions and Functions

Expendables are in standardized packages so that mixed types can be loaded into the same dispenser. Expendables are released automatically or manually.

Lethal defense weapons include a short-range high-g missile capable of attacking AIs and launched long-range missiles. Air-to-ground radiation homing or TV contrast lock-on missiles, guns, and other weapons are used in the dual role of attack and self-defense. Decoys can be loaded in lieu of weapons. Weapons and decoys are programmed and controlled by the stores management system.

Passive penetration aids include radar and IR aircraft cross-section reduction. Vulnerability is reduced by use of armor in critical part locations, and by special structure designs. Ablating and reflecting materials on critical surfaces reduce vulnerability to LASER weapons.

The penetration aid system and interface block diagram is shown in Figure 26.

Normally, penetration aid system operation is automatic. The pilot is kept informed by the battle situation display. The display is a PPI type with the tactical aircraft centered. It provides threat location and identity priority and shows the assigned offensive, defensive action. Voice warnings are provided for new threats and attacking terminal threats.

Located threats are represented with a cross shown at proper range and bearing from the fighter. Threat identity and type are on the upper left quadrant of the cross, priority upper right, relative altitude lower left, and assigned action lower right. Dashes are placed in the quadrants when data are unavailable or impertinent. Strobes (dashed lines) are placed on the display when range measurements are not or cannot be made, such as when the threat is jamming and denying range.

Threat priorities are automatically assigned on a first, second, third potential intercept basis. Priorities on the battle situation display for threats are: terminal--red; immediate--amber; delayed--blue; safe--green.

The assigned action for the first priority threat is destruction as shown on the battle situation display. The threat is almost within attack range. The selected weapon(s), attack range envelope is presented as a fan pattern on the MPD. The weapon(s) may be released manually after the threat penetrates into the outer limit of the attack envelope. The fire control symbol, moving

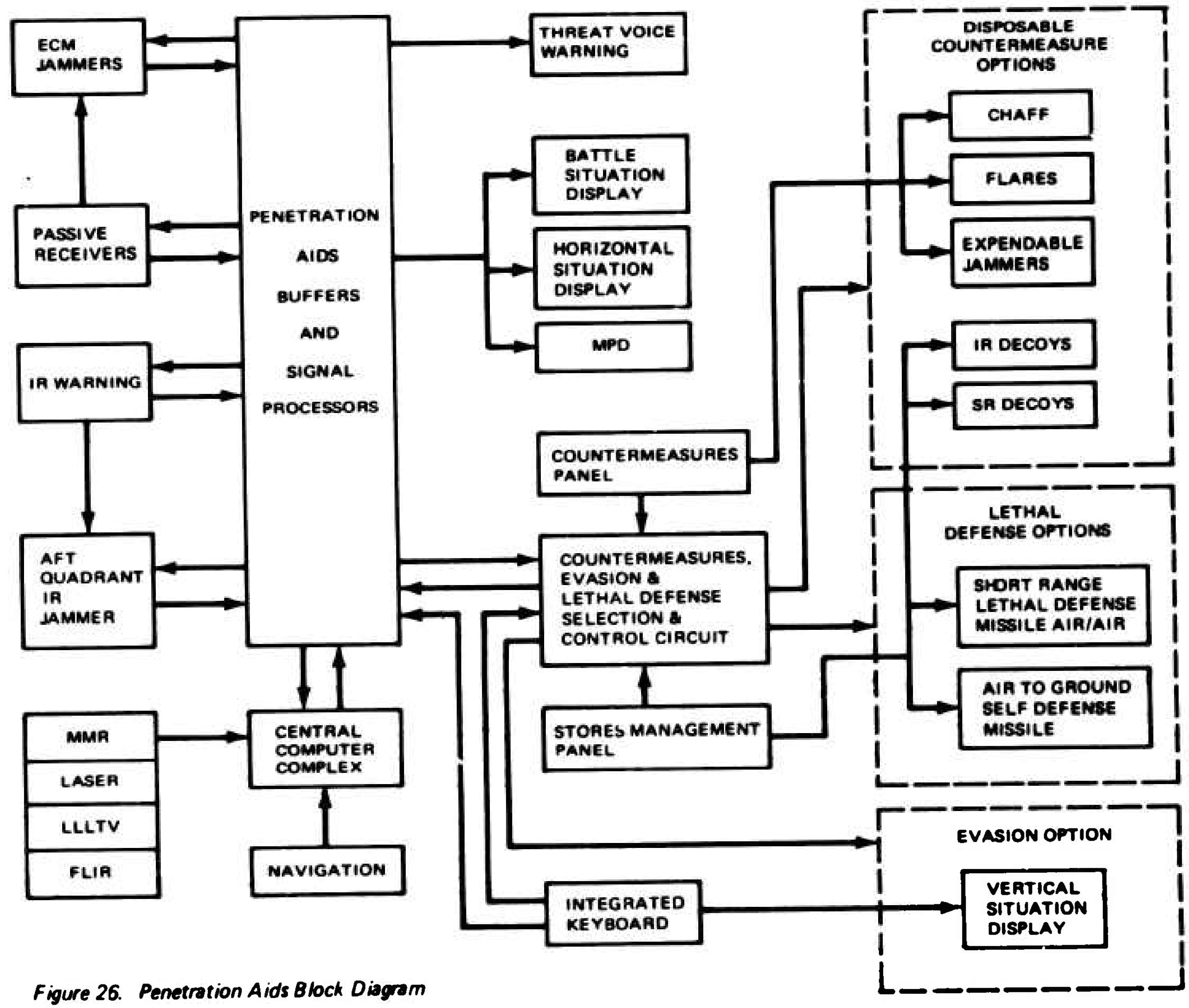
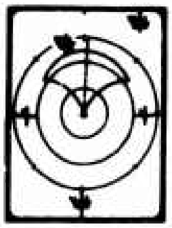


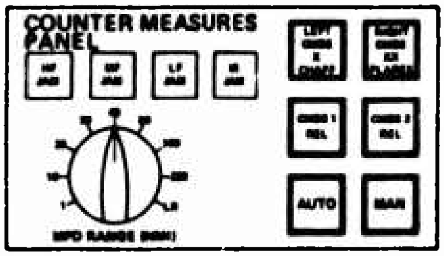
Figure 26. Penetration Aids Block Diagram

counterclockwise, is now at the 6 o'clock position. Manual release is now possible. Automatic release occurs at optimum range, the 3 o'clock position. Minimum range occurs at the 12 o'clock position.



If the decision is to evade, the weapon launch envelope and fire control symbol would not be shown. A voice and visual warning is given and ITEMS controls the evasive maneuver. When the threat is successfully bypassed, the threat priority is reordered.

If degradation (ECM) option is used, a voice warning is given and the proper system is tuned in automatically. Colored, lighted buttons on the countermeasure (CM) panel indicate the system is operating. Countermeasure system operating details such as expendables remaining are shown on the selected MPD.



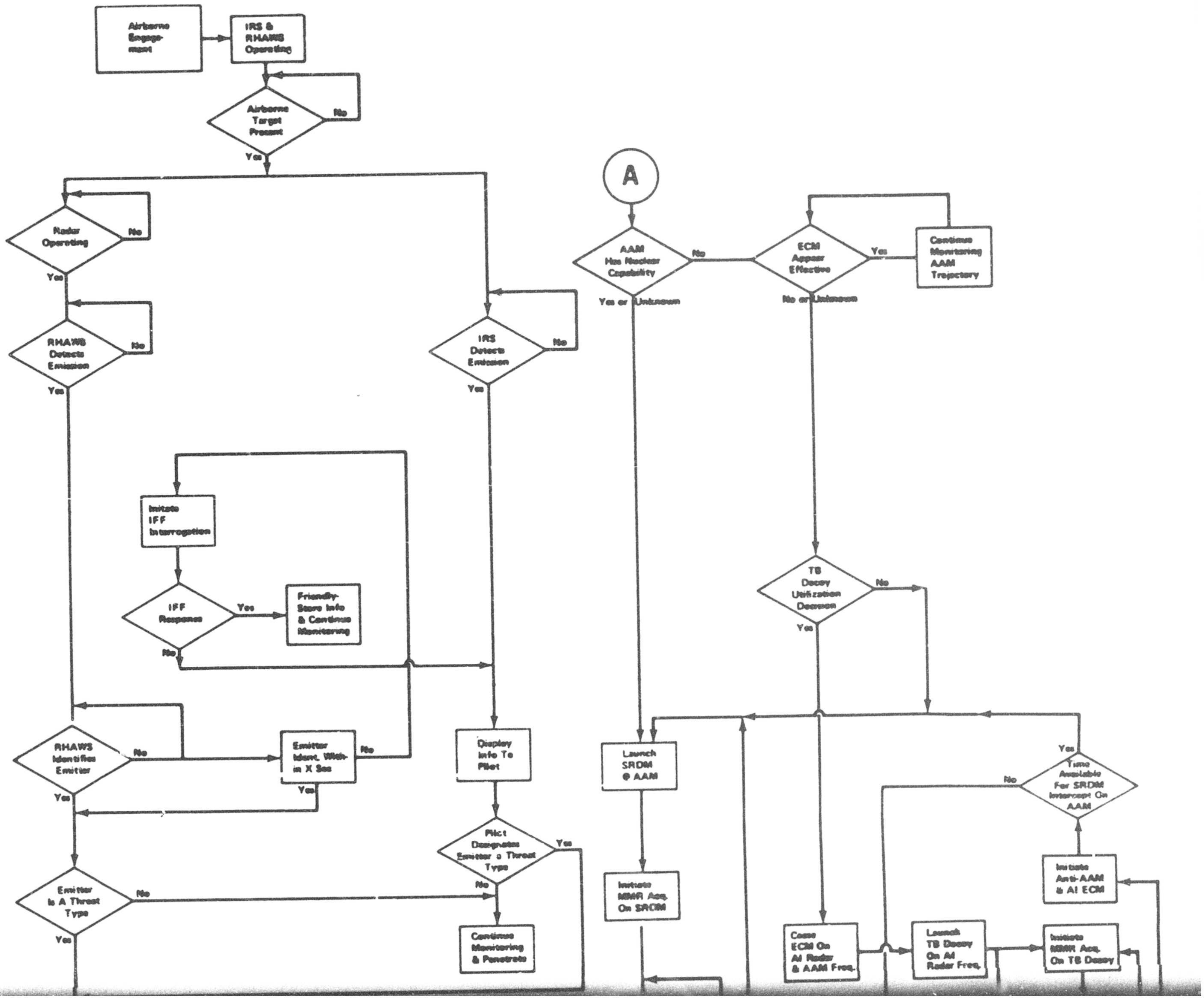
The effectiveness of offensive and defensive actions is automatically determined and displayed. If the threat priority does not change in a reasonable time, alternate or complementary actions are executed automatically. Appropriate warnings (flashing priority number) are presented on the display. If the priority does change, operations are completed or continued until the threats are no longer of concern.

The computer stores threat characteristics and countermeasure techniques for future use.

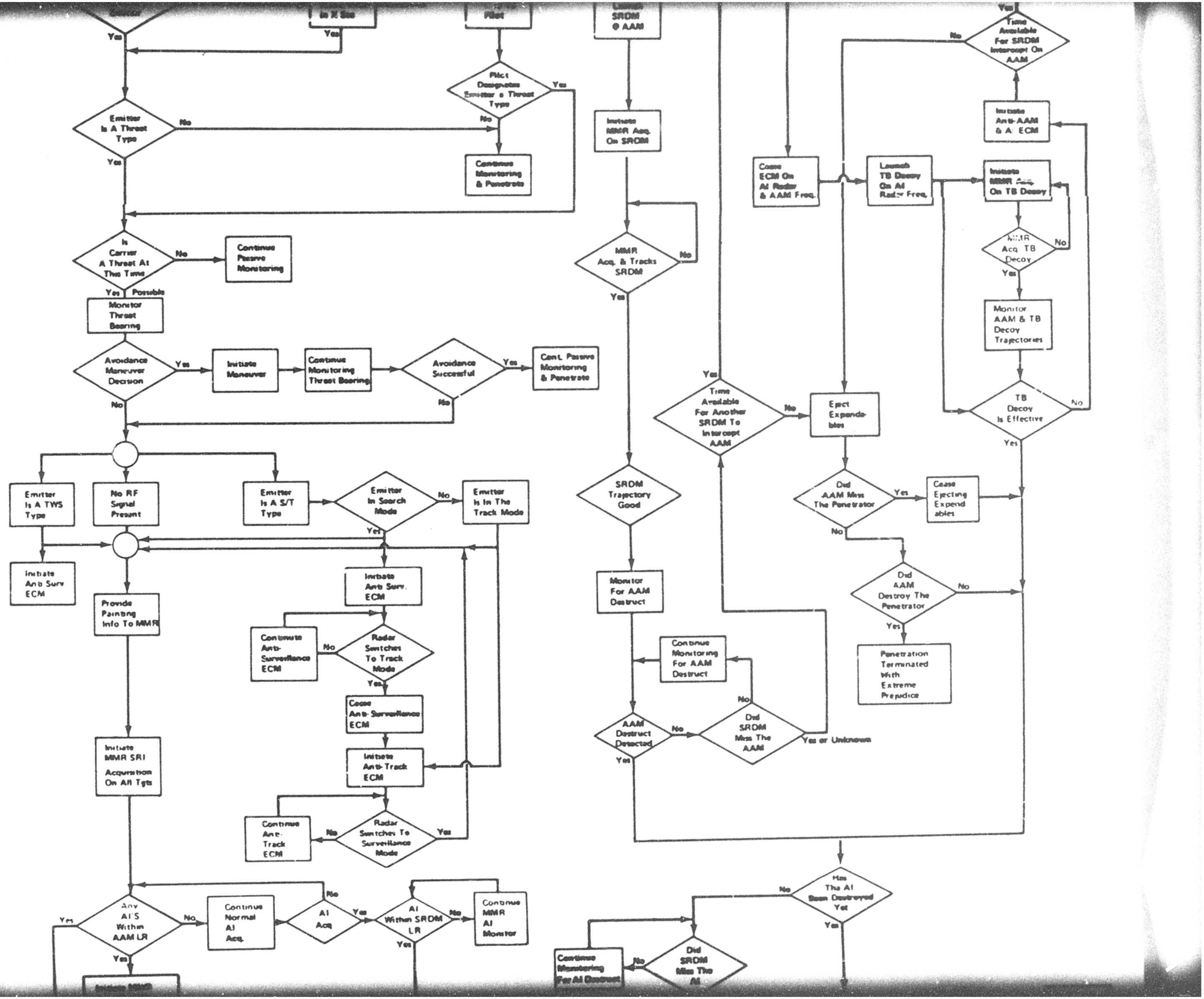
Typical logic showing the self-defense workload and decision process for an air-to-air and a ground threat has been developed. Results of the analysis are shown in Figures 27 and 28.

Logic decisions apply to either the pilot or the automatic system. The logic decision tasks shown are for a single threat. The workload would increase in direct proportion to the number of threats engaged.

Due to the complexity and workload involved in performing the decision logic process, it is totally automated. The significant results of the decision process are displayed as coded information on the threat cross of the Battle Situation Display (BSD).



Airborne Engagement
IRS & RHAWS Operating
Airborne Target Present
Yes
No
Radar Operating
RHAWS Detects Emission
IRS Detects Emission
Initiate IFF Interrogation
IFF Response
Friendly-Store Info & Continue Monitoring
RHAWS Identifies Emitter
Emitter Ident. Within X Sec
Display Info To Pilot
Pilot Designates Emitter a Threat Type
Emitter Is A Threat Type
Continue Monitoring & Penetrate
A
AAM Has Nuclear Capability
Yes or Unknown
ECM Appear Effective
No or Unknown
Continue Monitoring AAM Trajectory
TB Decoy Utilization Decision
Launch SRDM @ AAM
Initiate MMR Acq. On SRDM
Time Available For SRDM Intercept On AAM
Initiate Anti-AAM & AI ECM
Cease ECM On AI Radar & AAM Freq.
Launch TB Decoy On AI Radar Freq.
Initiate MMR Acq. On TB Decoy



Emitter Is A Threat Type
Pilot Designates Emitter a Threat Type
Continue Monitoring & Penetrate
Is Carrier A Threat At This Time
Continue Passive Monitoring
Monitor Threat Bearing
Avoidance Maneuver Decision
Initiate Maneuver
Continue Monitoring Threat Bearing
Avoidance Successful
Cont. Passive Monitoring & Penetrate
Emitter Is A TWS Type
No RF Signal Present
Emitter Is A S/T Type
Emitter In Search Mode
Emitter Is In The Track Mode
Initiate Anti Surv ECM
Provide Painting Info To MMR
Initiate Anti Surv. ECM
Continue Anti-Surveillance ECM
Radar Switches To Track Mode
Cease Anti-Surveillance ECM
Initiate Anti-Track ECM
Continue Anti-Track ECM
Radar Switches To Surveillance Mode
Initiate MMR SRI Acquisition On All Tgts
Any AI'S Within AAM LR
Continue Normal AI Acq.
AI Acq
AI Within SRDM LR
Continue MMR AI Monitor
Launch SRDM @ AAM
Initiate MMR Acq. On SRDM
MMR Acq. & Tracks SRDM
SRDM Trajectory Good
Monitor For AAM Destruct
Continue Monitoring For AAM Destruct
AAM Destruct Detected
Did SRDM Miss The AAM
Yes or Unknown
Time Available For Another SRDM To Intercept AAM
Cease ECM On AI Radar & AAM Freq.
Launch TB Decoy On AI Radar Freq.
Initiate MMR Acq. On TB Decoy
MMR Acq TB Decoy
Monitor AAM & TB Decoy Trajectories
TB Decoy Is Effective
Time Available For SRDM Intercept On AAM
Initiate Anti-AAM & AI ECM
Eject Expendables
Did AAM Miss The Penetrator
Cease Ejecting Expendables
Did AAM Destroy The Penetrator
Penetration Terminated With Extreme Prejudice
Has The AI Been Destroyed Yet
Did SRDM Miss The AI
Continue Monitoring For AI Destruct
Yes
No
Possible

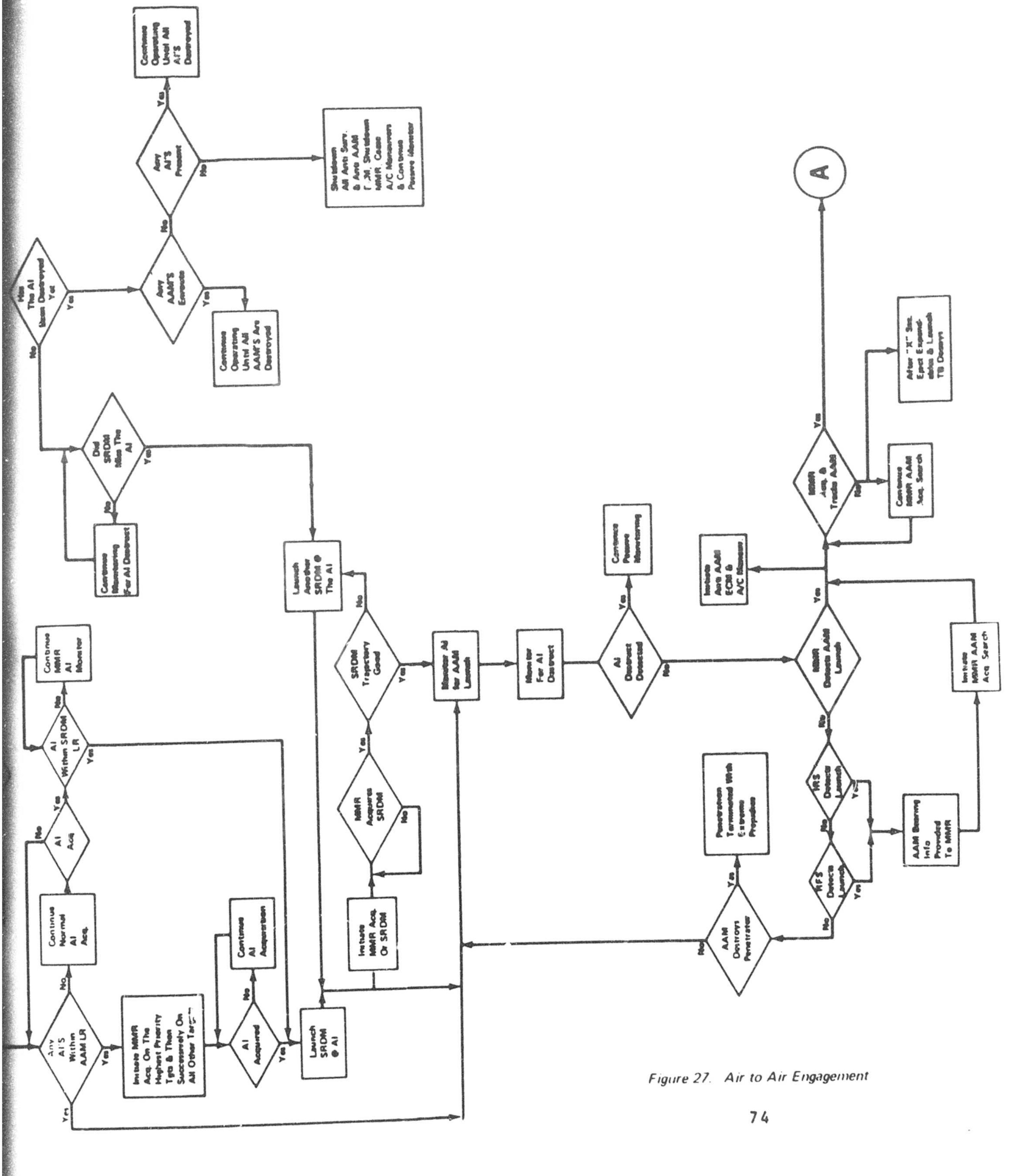
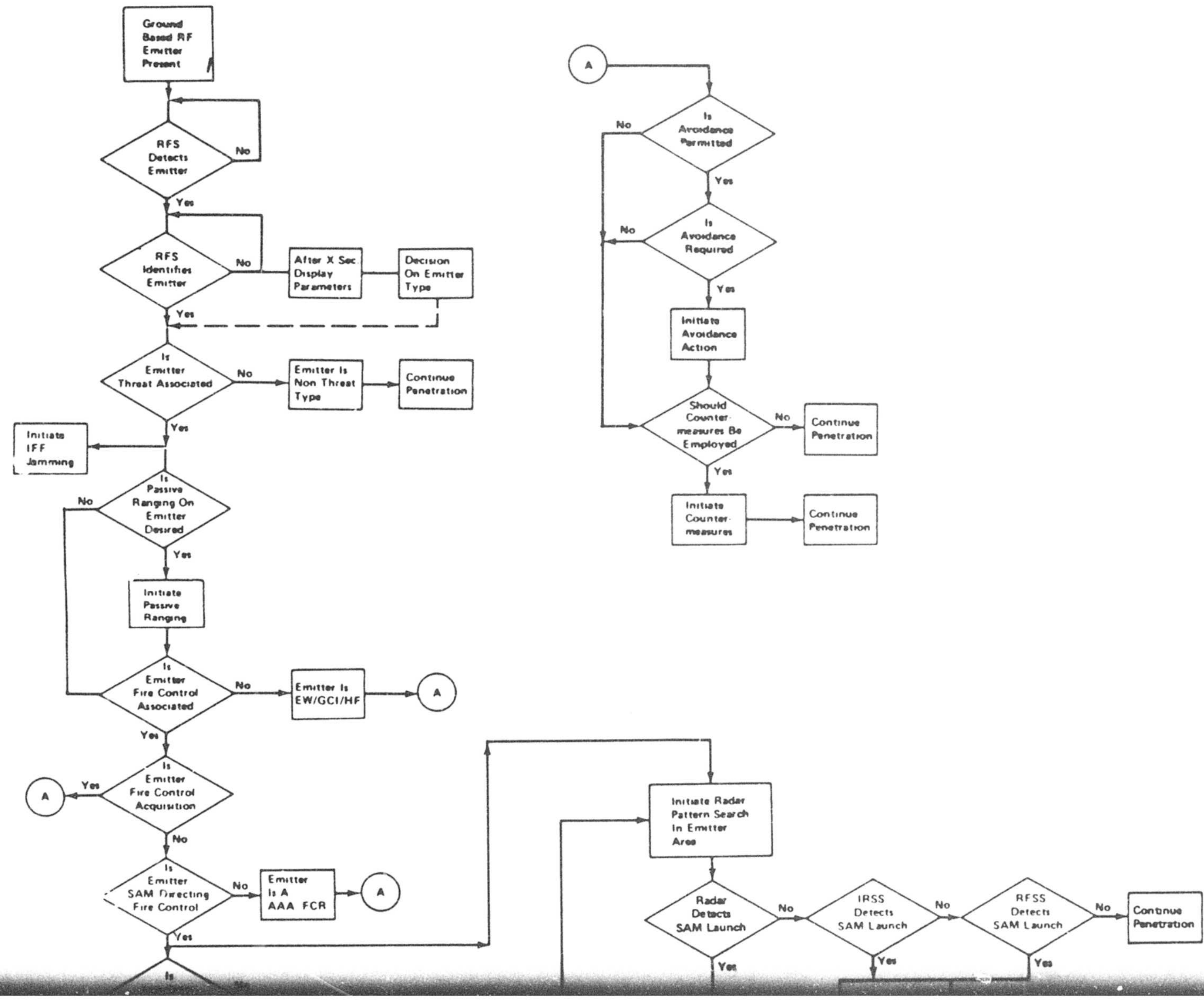
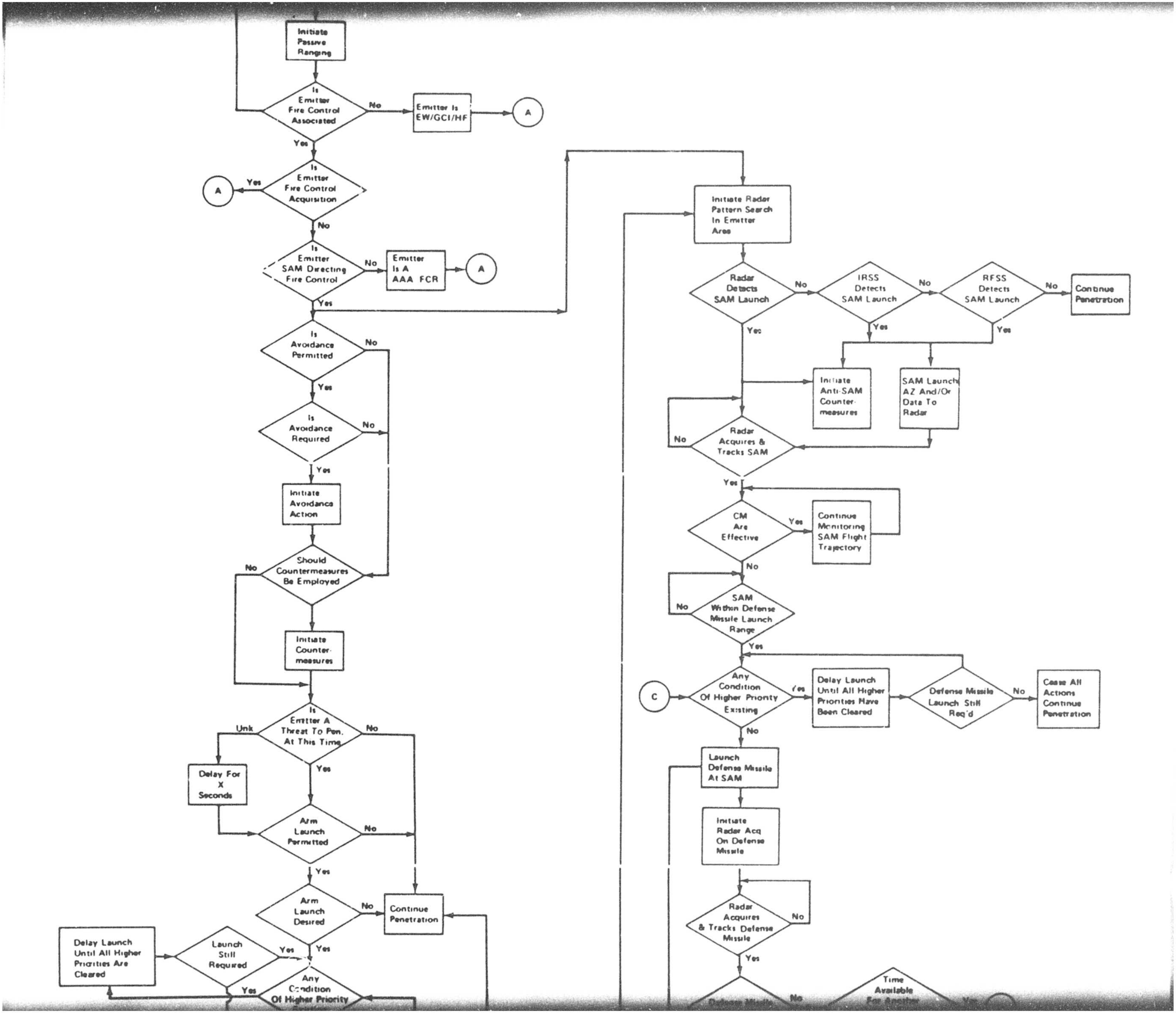


Figure 27. Air to Air Engagement



Ground Based RF Emitter Present
RFS Detects Emitter
No
Yes
RFS Identifies Emitter
No
After X Sec Display Parameters
Decision On Emitter Type
Yes
Is Emitter Threat Associated
No
Emitter Is Non Threat Type
Continue Penetration
Yes
Initiate IFF Jamming
Is Passive Ranging On Emitter Desired
No
Yes
Initiate Passive Ranging
Is Emitter Fire Control Associated
No
Emitter Is EW/GCI/HF
A
Yes
Is Emitter Fire Control Acquisition
Yes
A
No
Is Emitter SAM Directing Fire Control
No
Emitter Is A AAA FCR
A
Yes
A
Is Avoidance Permitted
No
Yes
Is Avoidance Required
No
Yes
Initiate Avoidance Action
Should Counter-measures Be Employed
No
Continue Penetration
Yes
Initiate Counter-measures
Continue Penetration
Initiate Radar Pattern Search In Emitter Area
Radar Detects SAM Launch
No
IRSS Detects SAM Launch
No
RFSS Detects SAM Launch
No
Continue Penetration
Yes
Yes
Yes


Initiate Passive Ranging
Is Emitter Fire Control Associated
No
Yes
Emitter Is EW/GCI/HF
A
Is Emitter Fire Control Acquisition
Yes
No
A
Is Emitter SAM Directing Fire Control
No
Yes
Emitter Is A AAA FCR
A
Is Avoidance Permitted
No
Yes
Is Avoidance Required
No
Yes
Initiate Avoidance Action
Should Countermeasures Be Employed
No
Initiate Counter-measures
Is Emitter A Threat To Pen. At This Time
Unk
No
Yes
Delay For X Seconds
Arm Launch Permitted
No
Yes
Arm Launch Desired
No
Yes
Continue Penetration
Delay Launch Until All Higher Priorities Are Cleared
Launch Still Required
Yes
Yes
Any Condition Of Higher Priority
Initiate Radar Pattern Search In Emitter Area
Radar Detects SAM Launch
No
Yes
IRSS Detects SAM Launch
No
Yes
RFSS Detects SAM Launch
No
Yes
Continue Penetration
Initiate Anti-SAM Counter-measures
SAM Launch AZ And/Or Data To Radar
Radar Acquires & Tracks SAM
No
Yes
CM Are Effective
Yes
No
Continue Monitoring SAM Flight Trajectory
SAM Within Defense Missile Launch Range
No
Yes
C
Any Condition Of Higher Priority Existing
Yes
No
Delay Launch Until All Higher Priorities Have Been Cleared
Defense Missile Launch Still Req'd
No
Cease All Actions Continue Penetration
Launch Defense Missile At SAM
Initiate Radar Acq On Defense Missile
Radar Acquires & Tracks Defense Missile
No
Yes
No
Time Available For Another

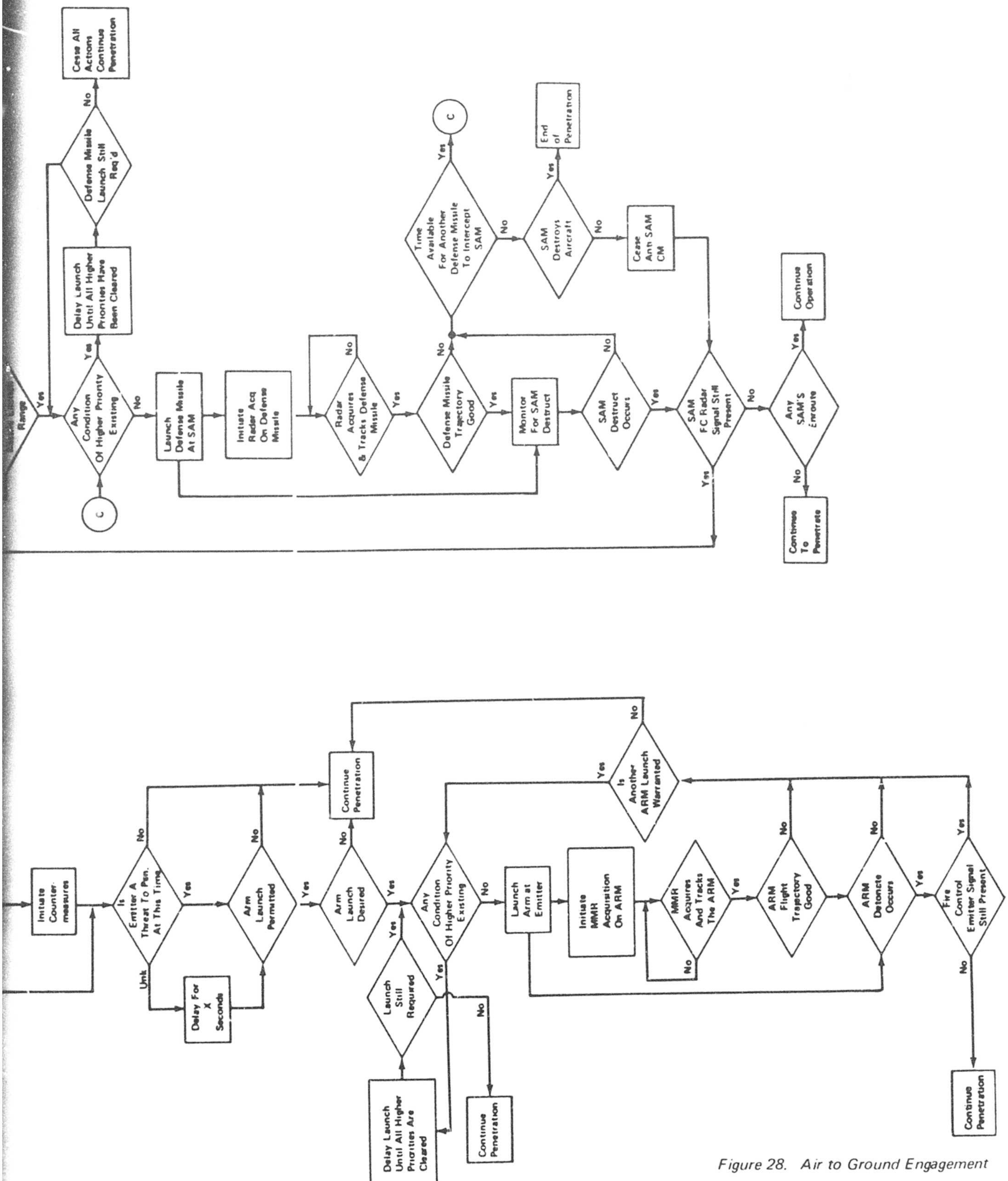


Figure 28. Air to Ground Engagement

m. Stores Management System

The prime purpose for the tactical fighter is weapons delivery. As such, all systems related to the aircraft are oriented to achieve this end. Consequently, the stores management system (SMS) depends both directly and indirectly on virtually every system involved in the placement of the appropriate store on the specific target.

Pounds payload per target destroyed is a primary weapon system figure of merit. To minimize expended payload, precision weapon delivery is necessary. Weapon delivery accuracy requirements, which for some targets may be about 10 to 50 feet, directly influence critical design parameters of all fire control sensors and the navigation system.

All-weather operation is required to continuously maintain a tactical advantage. Visual delivery and delivery with options selected from the full complement of on-board sensors are needed for flexibility. Precision data link or navigation-system-controlled automatic blind (no pilot control operation) weapon delivery is desired for preplanned targets.

High survivability is a requirement. High maneuverability and rapid speed changes are necessary to evade enemy actions. Weapons should be deliverable while evasive tactics are being performed. Self-defense is needed. Weapons for counterattacks should be carried.

Weapon options using a full spectrum of delivery tactics should be possible to optimize weapon accuracy in a variety of terrain, weather, and threat environments.

The SMS integrates all equipment affecting weapon delivery. The elements of weapon delivery include but are not limited to:

- Transfer of coded stores logic unit information on the weapon and its location
- Preprogramming, storage, and recall of complete or partial stores delivery programs
- Fuzing power, status, selection, etc.
- Data transmission
- Weapon environment such as aerosols (dust, bugs, ice, precipitation) and their effect on optics; temperature history; radiation; electromagnetic pulse, etc.

- Release parameters affecting look angle on guided weapons or the flight path of ballistic weapons (such as local air flow, acceleration, hook or rail drag, aircraft mass, and other factors impacting ejection velocities)

- Energy management integration into the fire control system and displays

- Weapon release/weapon away information

- Computing delivery envelopes and stepping to the next weapon envelope as the store is expended or its release parameters are compromised

- Jettisoning and automatic safe jettisoning coupled with the ITEMS

- In-flight training/simulation

Representative data showing typical parameters for MPD displays and special integrated keyboards are shown in Figure 29. Figure 30 shows stores management system functional block diagram.

n. Target Acquisition Sensors

The Automatic Target Acquisition system correlates data received from the MMR, LLLTV, FLIR, RHAW and IR warning systems. Sensor data are processed through the center computer complex and presented to the pilot on demand. Techniques such as the image registration process deal with the structure of the image as a whole, as opposed to the detailed comparison of individual resolution elements.

Four target acquisition sensors, low light and daylight television, FLIR with azimuth and elevation coverage forward of the airplane; radar with azimuth, elevation, and range capability; and LASER as a range only sensor, were assumed. These sensors are designed to have the same azimuth and elevation coverage so targets detected by each sensor can be positionally coordinated by the pilot on his display. The three major sensors can be presented simultaneously on the target acquisition display (VSD) for identification by superposition of target data from each sensor. For preplanned interdiction targets with known coordinates, the cursor appears at the top of the HSD at the predicted location.

COMPUTER COMPLEX	CLU CONTROL FUNCTIONS	STATION LOGIC UNIT FUNCTIONS	WEAPON CONTROL DISPLAY	
			Control Functions	Display Functions
Provide storage for: a. Mission Planning Data b. Threat Catalog Information Backup Programs Perform all weapon delivery computations and data processing such as: a. Navigation b. Bombing c. Air-to-Air Surface Missile Launch d. Penetration Aids e. Mission Control f. Integrated Testing g. System Interface Computation Functions	Mode Select Auto, Manual, Emergency, Test Store/Station Select Strike Option Selection a. Delivery Mode Auto Manual b. Fuze Options Nose; Tail; All; Timer/Delay; Air Burst; Ground Burst; Contact; Laydown c. Trajectory Options Hi Level; Lo Level; Hi-Lo; Lo-Hi; Max Ave; Max Pen; Retard; Free Fall d. Release Options Manual; Auto; Dive/Toss; Single-Pairs-Multiples Release Interval e. Gun Control Ammo Select; Fuze Select; Rate Select; Gun Charge/Safe f. Guidance Options (Missile) ARH, IR, Optical (Terminal) Frequency Command, Inertial Programmed (Mid-course) Strike Controls a. Prearm, Arm, Safe b. Rack Unlock c. Nuclear Consent (CSS) d. Wpn Release Jettison Controls All Selective	Logic/Memory a. Store type b. No Stores Remaining c. Store Parameters (Wgt., CG, Drag) d. Store Limits (cruise-delivery speed, g-limits, temperature, altitude) e. Delivery/Fuze Restrictions Store Status Safe, Arm, Go/No-Go Rack Status Locked Unlocked Store Environment Monitor	Store Selection a. Weapon identification b. Expendable identification Strike Option Selection a. Delivery Mode Selection 1) Radar Release 2) Timer Release 3) Manual Release 4) Emergency Release (Backup) b. Weapon Options 1) Air Burst 2) Ground Burst 3) Free Fall 4) Retard 5) Contact Burst c. Weapon Release/Launch Sequence 1) Single 2) Pairs 3) Multiple d. Weapon Release/Launch Rate Strike Control Selection a. Prearm/Safe Weapons b. Consent to Prearm Nuclear Weapons c. Consent to Release/Launch Nuclear Wpns Release Selection a. Normal (Automatic or Manual) b. Emergency c. Jettison 1) Conventional 2) Nuclear Preprogram, Recall & Modify Missile Guidance Master Arm Enable SMS Power On	Store Selection Strike Option Selection Strike Control Selection Release Selection Status: a. Store Stations Not Loaded b. Store Quantity Loaded c. Store Quantity at Each Station *d. Safe/Prearm Status of Wpn *e. Safe/Prearm Status of Nuclear Weapon *f. Lock/Unlock Status for Each Weapon g. Master Caution if items c. and f. disagree h. Carrier Restrictions due to: 1) Carrier Maneuver Restriction 2) Store Airspeed, "G" Restriction and Look Angle 3) Aircraft Weight 4) Location and Type of Stores Remaining 5) Aircraft Configuration (e.g., wing sweep, ldg. gear position, flap position) i. Stores Release/Stores Away j. Store Quantity Available at Each Station for Release, Launch, Firing, or Jettison k. Stores Malfunction l. SMS Equipment Malfunction *Continuous or On-Demand Indications

Figure 29. Stores Management Parameters

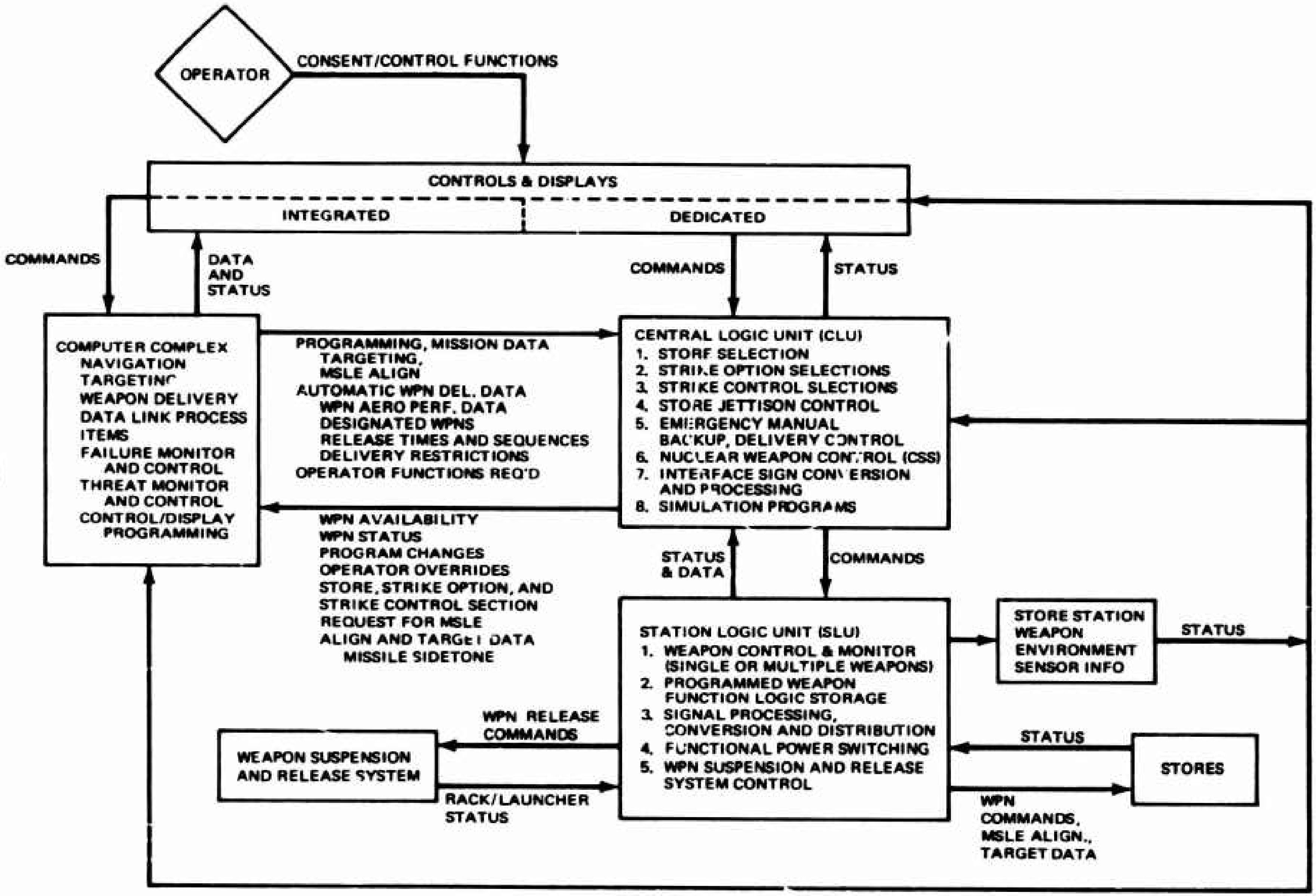


Figure 30. Stores Management System Functional Block Diagram

Of the possible radar techniques available in this period, the one that appears to offer the most promise is the multiple emitter/receiver. This radar uses solid-state devices to generate the RF power. The only degradation suffered when partial failure occurs in the transmitting elements is that the beam sharpness is reduced. Scanning is electronic with a computer stabilized beam.

Received signal processing is of the monopulse type. Complete azimuth elevation and range data are obtained from each transmitted pulse. The processing also sorts out returns that exceed the background noise and land echoes by a given amount. Then these returns are examined for location with respect to the predicted navigation coordinates of a preplanned target. A symbol that represents a processed radar target appears on the VSD and HSD at the appropriate location. The cursor corresponds to the predicted target location and is manually moved to the target to achieve lock-on, first on the VSD, then the HSD.

Under lock-on conditions, the computer begins to perform a track-while-scan operation based on the cursor azimuth, elevation, and range at the time the pickle switch is pressed.

FLIR is capable of locating targets in azimuth and elevation. It detects objects that differ in temperature with respect to the temperature of the surroundings. The general background temperature is determined by processing techniques. Depending on the type and the presumed temperature of the target, a temperature difference or presentation threshold is preselected. Returns having a greater temperature differential than this threshold are presented on the VSD. A cursor can be placed over the target to initiate contrast tracking. The FLIR receiver is slaved to the inertial platform through the computer to aid in tracking and to stabilize the presentation. Boresight and field of view for the FLIR must be the same as the TV and radar to achieve target identification by superposition.

Television and radar are the two principal sensors. Television can see targets under low light conditions that cannot be detected by the unaided eye. Also under daylight conditions, the pilot can coordinate returns from TV, radar, and IR. Color TV is required for daytime operation; otherwise, the pilot would look out of the cockpit for color cues. The TV camera is stabilized to the heading of the airplane, or to a preset azimuth angle for use with offset bombing techniques.

Two fields of view should be available to the pilot, a wide field for general search and a narrow field for identification. Two mechanizations are suggested: (1) electronically magnify the image; and (2) use two cameras, one with a broad field of view and a second camera with a small field of view and high resolution. Both images are presented on the VSD simultaneously with the high resolution image replacing a portion of the low resolution image at the correct relative location. Either of these techniques can be used for target identification.

The LASER is used as a ranging device to provide distance to the target when a discrete narrow beam is preferred, or the radar is inoperative, or when greater accuracy is required. Operation as an illuminator is not contemplated, because the TV can perform this task in a completely passive manner. Both media are subject to the same limitations of haze, fog, and clouds. The LASER provides range upon command by the pilot.

o. Battle Damage Assessment/Reconnaissance

The IIPACS weapon system can gather battle damage and/or reconnaissance data. On-board sensors sense the ground target area and aid in compiling sufficient data to determine target viability before and after a strike. Such information is transmitted through data link to the Battle Area Commander.

On-board equipment can detect and record sensor data from the MMR, LLLTV/FLIR, RHAW, and EMP measuring devices. In addition, targeting and weapon delivery information, navigation data, and voice recording are continuously available through tape decks for playback to the Command Post via data link. Such data may be requested at any time by the Command Post without assistance from the pilot.

During high/low altitude penetration, battle damage assessment (BDA) recordings are initiated automatically at a preset range or time before scheduled weapon release. Recordings continue through detonation for post-strike analysis.

During an operational situation, for example, the recording devices may be started either through computer instructions, data link, or manual commands using the keyboard.

Computer instructions come from preprogrammed time or range intervals before or after weapon detonation. Recording instructions for turn-on, turn-off and/or playback

may come also from data link or keyboard commands. The Battle Area Commander may receive near-real-time sensor data from the IIPACS aircraft. Such data may be examined for tactical value and used either to direct the aircraft for additional targeting or to provide assessment data for instructing following aircraft. The radio bandwidth is large enough to handle radar and electro-optical sensor information being data linked to the Command Post. Navigation, targeting, and weapon delivery information will accompany the recording data to make the imagery more useful in the final damage assessment analysis. All sensor imagery data would be recorded on digital tapes compatible with on-board digital equipment.

The BDA function would be selected from the "FCS" options presented on the Master Keyboard Select panel. Various options pertaining to BDA appear on multi-legend keys as shown on the example keyboard. Each key carries at least 48 different legends that selectively appear as various functions are performed.

The BDA system would normally be in AUTO where all programming would be handled through the central computer; however, the pilot may select MANUAL and start, stop, or play back any recording.

6. CONTROL/DISPLAY CONCEPTS

The study analyses were primarily oriented toward reducing the interpretive and integrative processes imposed on the pilot while he performs the complex mechanics of flying a sophisticated aircraft. The result of these analyses produced the concept of an ITEMS.

Energy management is by no means a new concept. Attempts at energy management first appeared with the issue of pilots' handbooks. The significance of energy management gained prominence with the appearance of the ME-163 toward the end of World War II. A. Leppisch, of ME-163 fame, may be credited with recognition of the refinement of energy management required for the optimization of high performance aircraft by developing idealized climb schedules. The most advanced work in the field is found in space vehicles and may be applied to aircraft.

Existing programs are reasonably accurate, but they are limited by deficiencies. Some of these deficiencies are identified by Dunlap (Ref. 2) as response time, display media, and the fact that they treat the problem almost exclusively in one plane of operation such as range-time altitude or zoom-climb. The requirement for the development of a three-dimensional total energy

management system in essentially real time is indicated in this study.

The proposed system dispenses with the requirement to present quantitative information. The ITEMS may be programmed to optimize a specific energy profile. Examples of some types, all in the vertical plane, are taken from Ref. 2. They are in part:

- o Minimum time climb
- o Minimum time altitude--range transition
- o Minimum fuel climb
- o Maximum range climb
- o Maximum range cruise
- o Maximum endurance cruise
- o Range-time-altitude rendezvous
- o Zoom climb to launch

Control of g location, flexibility of flight controller gains, and flight control harmonization are necessary adjuncts to the ITEMS concept to preclude energy losses and/or to provide an optimum weapon delivery platform. Vietnam data indicate a need exists for high-g maneuvers throughout a spectrum of speed ranges. Figure 31 shows the accelerations as a result of control excursions at specific Mach numbers for an existing fighter aircraft. Such control parameters compromise the operational capabilities of a weapon system regardless of stick force per g.

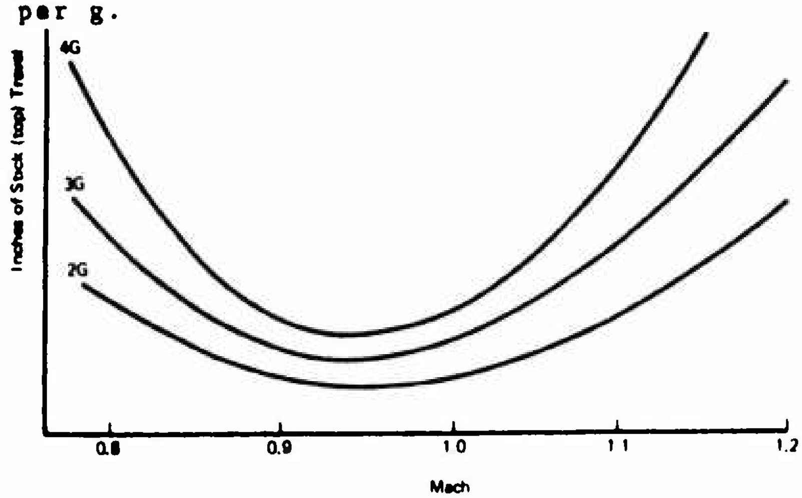
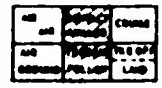


Figure 31. Relationship of Acceleration to Control Input as Affected by Mach Number

As each mode of flight is selected, the aircraft's stability and control characteristics change in addition to the associated displays. For example, selection of the air-to-air mode will cause the cg to move closer to the center of pressure to provide the decreased stability necessary to high maneuverability. Controller to control surface relationships gain will be altered to counter the adverse yaw associated with high roll rates at large angles of attack. Appropriate changes will occur as the cruise, landing, and air-to-ground modes are selected.



a. Cockpit Functional Layout

Personnel sizing and response to the environment dicated the IIPACS cockpit configuration. The cockpit functional layout was developed from three major inputs, the pilot's reach and vision envelopes, the control and display groupings, and the airplane configuration. The envelopes are divided into sectors of increasing access difficulty with respect to the eye reference point. The control and display groupings resulted from the analysis procedure, especially the ranking of these items as to their importance to safety of flight and mission completion.

The use of the eye reference point was found to be more realistic than the use of a seat reference, considering the variations that exist in the buttocks to eye dimensions. Target identity, target aiming, and visual landing depend on proper alignment of the target, a sight, and the pilot's eye. Therefore, the cockpit was designed around the eye reference point.

The pilot obtains proper eye position when he is fully restrained with seat and shoulder belts by aligning the eye with a reference provided by a collimated image and a physical feature of the airframe. Seat tilt for comfort is achieved by rotating the seat about the eye reference point.

With the eye position fixed, the control/display location limits were defined. According to Morgan (Ref. 3), viewing distance for controls and displays is limited by reach distance and should not exceed 29.5 inches. A minimum viewing distance of 13 inches is recommended; however, it should preferably be not less than 20 inches. For this study, a figure of 29 inches was used, resulting in a sphere of 29-inch radius about the eye reference point.

The primary, secondary, and tertiary viewing areas are defined in Figure 32. The primary viewing area is seen by moving only the eyes from the eye rest point which is forward and down 15° with respect to the horizontal. The secondary viewing area is seen by moving the head while retaining the eyes in a straight-ahead position. The tertiary viewing area is seen by a combination of eye and head movement.

The primary reach area is defined as the volume that can be reached by both hands while fully restrained by the seat belt and shoulder harness; i.e., either hand may be used on the control. Morgan (Ref. 3) defines this volume as being 24 inches wide and extending out and up from a point corresponding to the center of the pilot's fist when the forearm is horizontal and the elbow is next to the body. The far end of this reach volume is obtained from the extension of the arm as far as possible in a horizontal path. The top is obtained by raising the arm to a 15° position, first with the elbow next to the body, then extended horizontal from the shoulder.

The secondary reach volume is that area in which the pilot may operate any type of control easily using only one hand. Operation of these controls requires turning, clamping, pushing, and pulling. The tertiary volume is defined as that volume in which only limited types of controls, such as toggles or pushbuttons, can be operated easily. The reach areas are delineated on Figure 33.

Aircraft configuration constrained the instrument panel size. The conical shape of the mockup, which gives the pilot considerable shoulder room, results in a reduced cross-sectional area at the instrument panel, 29 inches forward of the eye reference point.

Further examination of the reach envelopes indicated the lap area above the pilot's legs is also a primary reach area. A removable lap panel was evaluated, and it was decided to attach a lap panel to the forward panel and to mount this assembly on the side-hinged canopy, Figures 34 and 37. Thus, a wraparound effect was achieved while pilot ingress-egress was made easier and access to instruments was improved.

A conventional flat forward instrument panel was designed as an alternate configuration (Figure 35). This panel is attached to the airframe and has separate side panels which butt up against the forward panel. A unique feature of this cockpit configuration is the movable armrests that provide the pilot greater comfort and improved

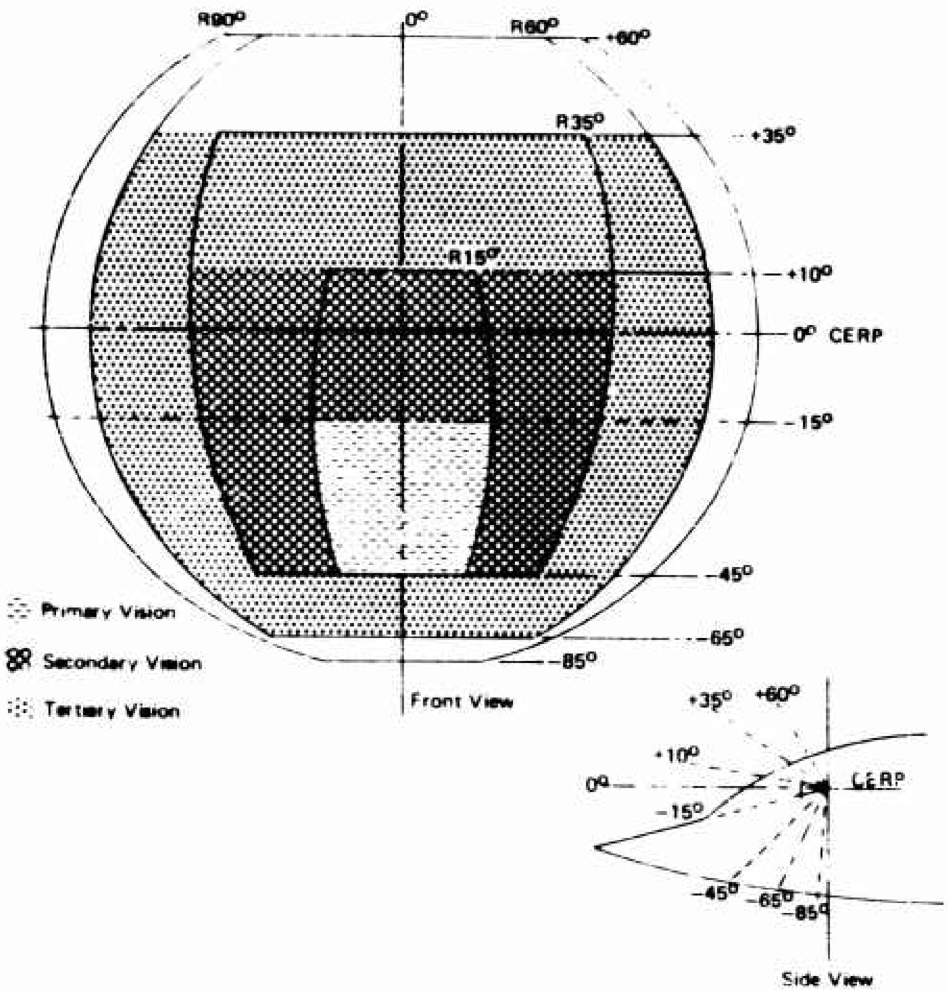


Figure 32. P.iot Vision Areas

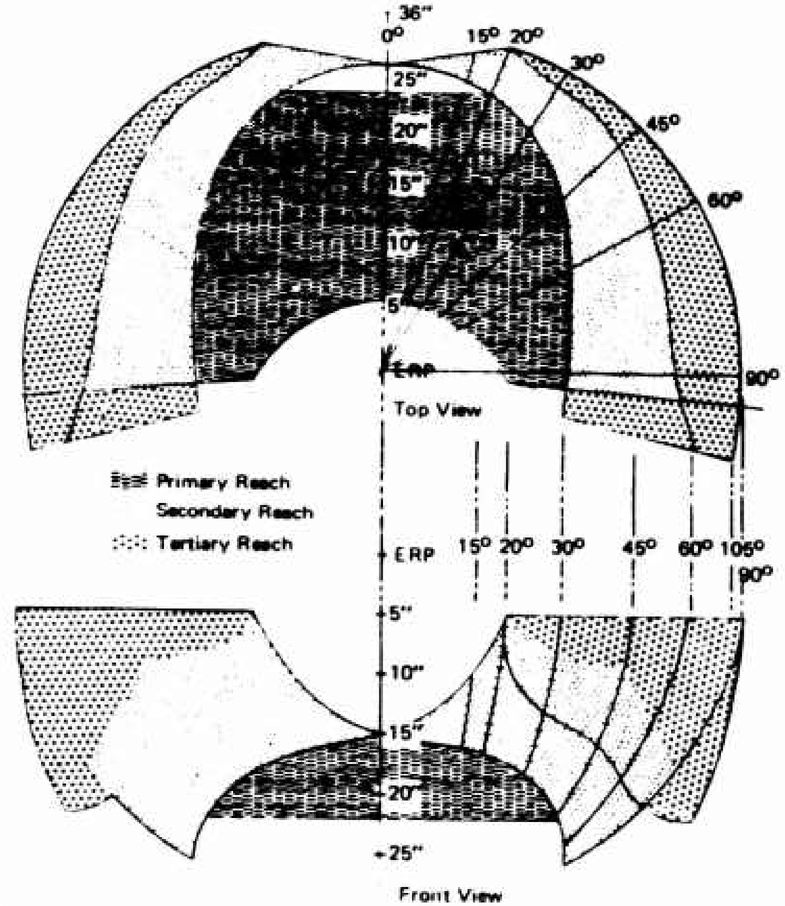


Figure 33. Pilot Reach Areas

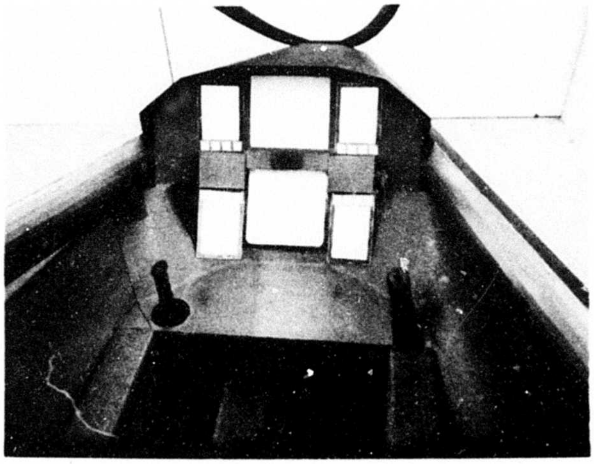


Figure 34. Wraparound Functional Layout

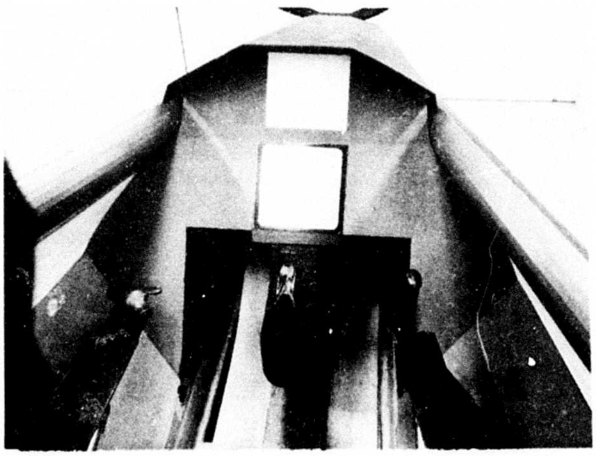


Figure 35. Center Stick Console Functional Layout

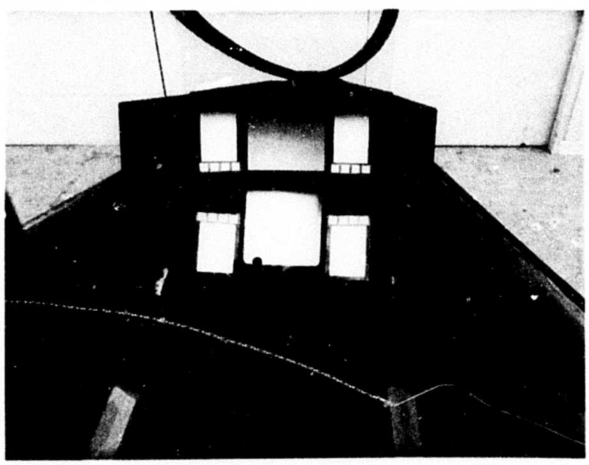


Figure 36. Panel Mounted Control Handle Functional Layout

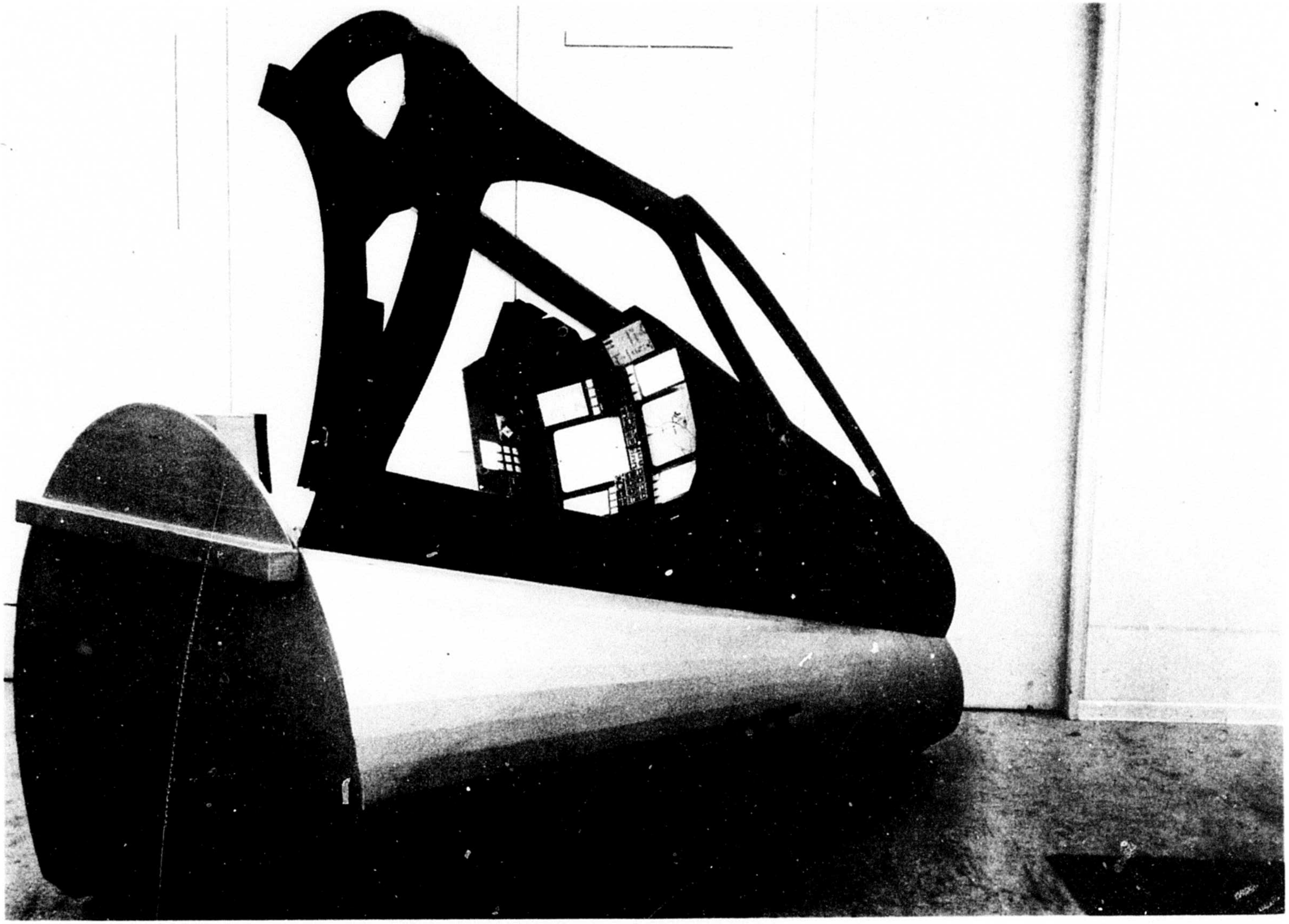


Figure 37. Instrument Panel Raised With Canopy—Wraparound Cockpit

ingress/egress. The armrests move laterally. The flight control stick is center-located.

The third configuration falls between the two described above. It has many features of the wraparound concept including the raising of the instrument panel with the canopy. This configuration uses panel-mounted control handles--flight controls that extend out of the instrument panel and are gripped comfortably with each hand (with the forearms on the armrests). This concept is shown in Figure 36.

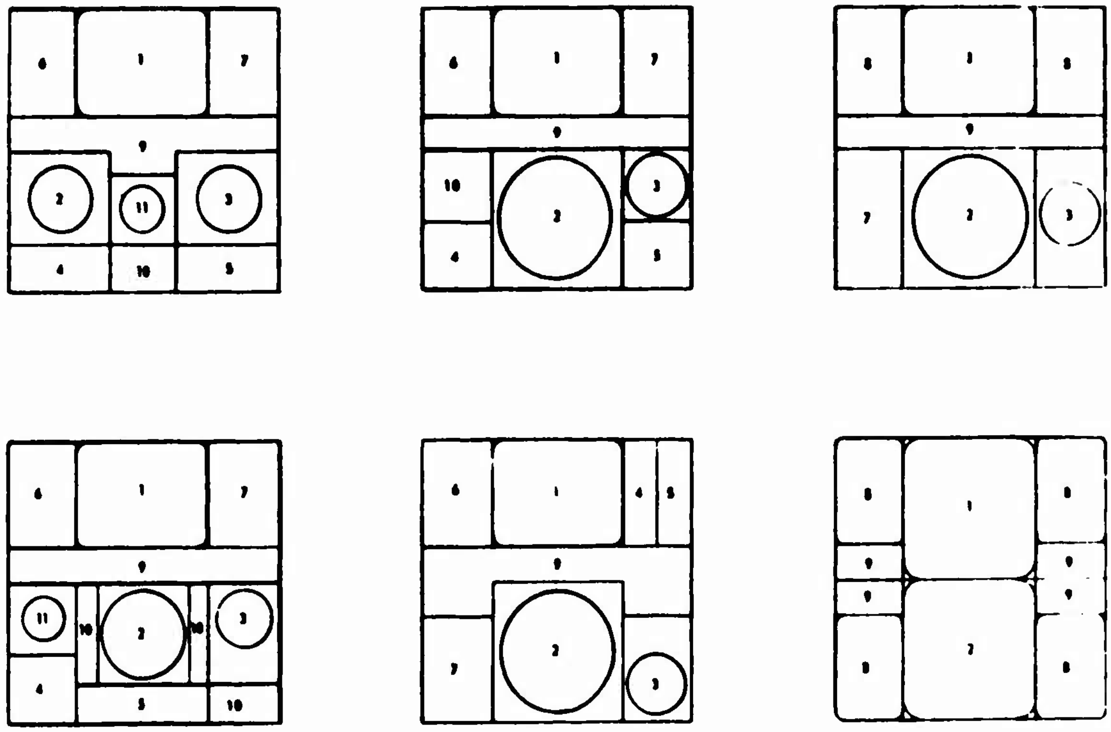
b. Control/Display Definition

The analysis described in detail in Vol. II, Section III, defined the controls and displays included in the cockpit. To determine where these controls and displays should be located with respect to the reach and vision envelopes, each task was rated as to its importance. These ratings governed task assignment to primary, secondary, or tertiary reach or vision areas. Three possible mechanization schemes were postulated for each control/display function. This resulted in trade studies being performed to define the relative advantages and disadvantages. Each control and display was initially treated as an independent entity with grouping to be considered during integration. Six alternate panel arrangements were developed and are shown in Figure 38. A combination of configurations 3 and 6 of the Figure was selected.

Traditionally, controls have been grouped by subsystem; however, the results of this analysis called for similar functions to be performed on a common panel. Once the common functions were defined and grouped, the remaining functions associated with a given equipment type were associated together. For example, all navigation controls (whether for an inertial platform or a TACAN) are on the same panel. Secondary and tertiary controls may be upgraded, but a control may not be downgraded to a lower ranked area.

Time-sharing was considered in selecting control/display mechanizations. The use of time sharing minimized the multitude of special-purpose controls and displays prevalent in today's airplanes. This is especially true of displays.

A primary requirement for the tactical fighter system is a superior all-weather, air-to-ground target acquisition capability. Radar, FLIR, low-light level and daylight TV, and LASER sensors were selected to provide targeting information. Boeing-Wichita studies of display



LEGEND

1. VERTICAL SITUATION DISPLAY (VSD)
2. HORIZONTAL SITUATION DISPLAY (HSD)
* 3. PASSIVE BATTLE SITUATION DISPLAY (BSD)
* 4. COMMUNICATION, NAVIGATION, IDENTIFICATION DISPLAY (CNI)
* 5. PRIMARY NAVIGATION DISPLAY
* 6. ENERGY MANAGEMENT DISPLAY (ITEMS)
* 7. WEAPONS STATUS DISPLAY
8. MULTIPURPOSE DISPLAY
9. DISPLAY CONTROLS
10. SECONDARY CONTROLS – GROWTH SPACE
11. HORIZONTAL NAVIGATION INDICATOR

* MAY BE REPLACED BY MULTIPURPOSE DISPLAY

Figure 38. Proposed Panel Layouts for Primary Vision Area

sizes for a combination of radar, IR, and TV sensors (Ref. 4) recommended a display size of 6 by 8 inches at a viewing distance of 30 inches. Working with these dimensions and considering the need for horizontal targeting information, two central panel displays were stacked vertically with a space between them for sensor and flight mode selection. The panel space remaining would not accommodate conventional miniature instruments and the remaining control functions. A time-sharing concept using multipurpose displays (MPD's) evolved. These time-shared displays are large enough to provide meaningful information for data that do not require continuous readout.

A HUD for use under visual and transitional conditions was placed above the centrally located VSD and HSD. These primary displays present essential aircraft control and targeting information.

The MPD's are secondary and/or contingency displays that may be used to augment primary displays. The type of information presented on these displays includes engine data, battle situation, communications selections, etc. The MPD's are used intermittently or are monitored quite closely depending on the parameters displayed and the mission segment. With one exception, these MPD's are located in the primary viewing area.

Building on the two primary displays and the four MPD's grouped about them, the remaining controls and displays were allocated to reach and vision areas based on their relative importance. The resulting cockpit functional layout is shown in Figure 39. This layout only applies to the wraparound cockpit. Variations of this layout are used for the other two cockpit configurations.

(1) Primary Displays

Primary displays present essential and ancillary information to the pilot for monitoring during automatic flight or for direction during manual control of the airplane. These essential data include command information to tell the pilot what he should do or what is being done for him to carry out the assigned mission. The ancillary information contributes to the pilot's confidence or is used only for specific flight phases.

Primary displays fall into a head-down or head-up category. It is well known that a finite time is required to refocus the eyes from near to far and from far to near objects. Many factors enter into accommodation

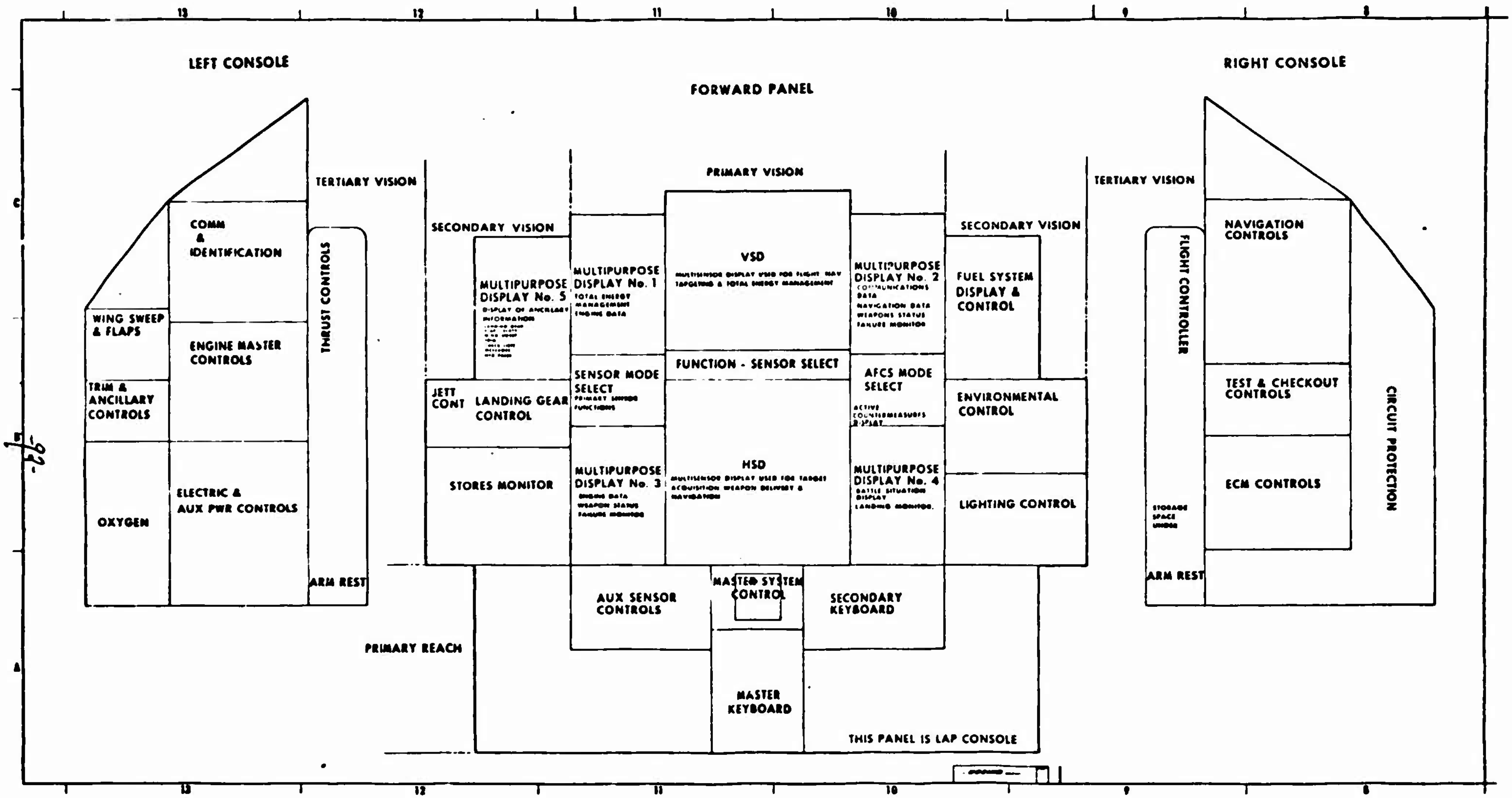


Figure 39 IIPACS-1 Wraparound Cockpit Functional Layout

time. A principal one is age. Data on accommodation inertia (focusing time) obtained in the Boeing Visiometrics Laboratory indicate the time to obtain a clear image when the observer shifts from near visual tasks to extra-cockpit vision can be significant.

Figure 40 reflects the factor of age as the contrast, in near to far refocusing time, for two age groups. Figure 41 shows that the duration of the near task, at an instrument distance of 26 inches, is a factor. After 30 seconds, refocusing to distance takes 3.2 seconds and this increases at 0.3 second per minute up to four minutes. The low illumination condition of a pilot's environment at night has a greater effect on refocusing time than a higher illumination condition as shown in Figure 42.

Two courses of action are open to resolve this problem. One solution suggests the potential benefit that may be obtained from eyeglasses with special bifocal lenses that obviate the requirement for changes in focus, and enhance visual performance even for the younger pilot. These lenses would permit the pilot to remain focused at a distance, even when viewing the instruments. An alternate solution is that either of the two display types (VSD and HUD) should independently provide sufficient information during critical mission segments to permit continuous pilot attention either in or out of the cockpit.

(a) Head-Up Display (HUD)

The more conventional HUDs have a relatively large case closely associated with and attached to a combining glass. HUDs of this type are considered incompatible with the tactical attack fighter cockpit configuration. To obtain the minimum field of view (16°) with a conventional HUD, the combining glass should be placed from 20 to 26 inches from the eye reference point. The remainder of the displays are placed at 29 inches. There are two reasons for not placing a conventional HUD further from the eye; the first is that the subtended angle between the eye and the outline of the combining glass is reduced; the second is the reduction of vertical space available due to the convergence of the cowl and windshield.

Two other types of HUDs are available, both bringing the combining glass close to the eyes. One mounts a small-sized binocular HUD to the airframe (Figure 43); the other places it on the pilot's helmet (Figure 44). Each of these approaches has drawbacks. The prime problem with the HUD attached to the airframe is relative motion between the pilot's head and the display. The helmet-mounted display allows the pilot to look in all directions,

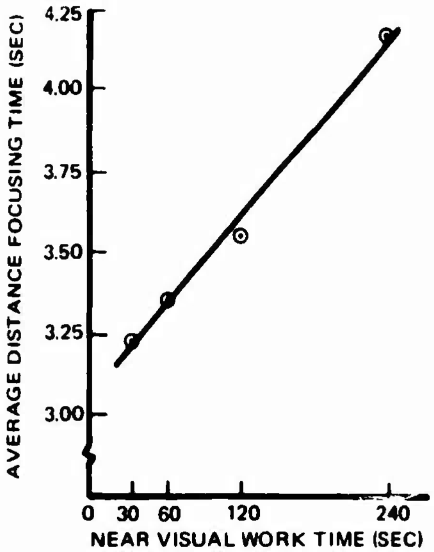


Figure 40: Average Time for 35 Observers (Ages 21 to 55) to Change Focus From 26 Inches to 20 Feet (Infinity)

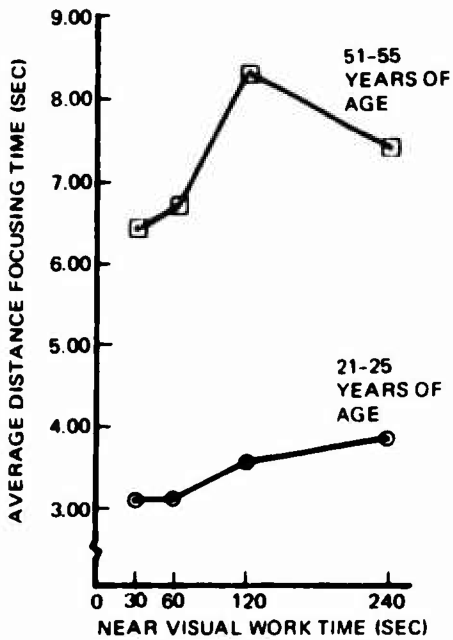


Figure 41: Time Required to Change Focus from Near to Far for Two Different Age Groups

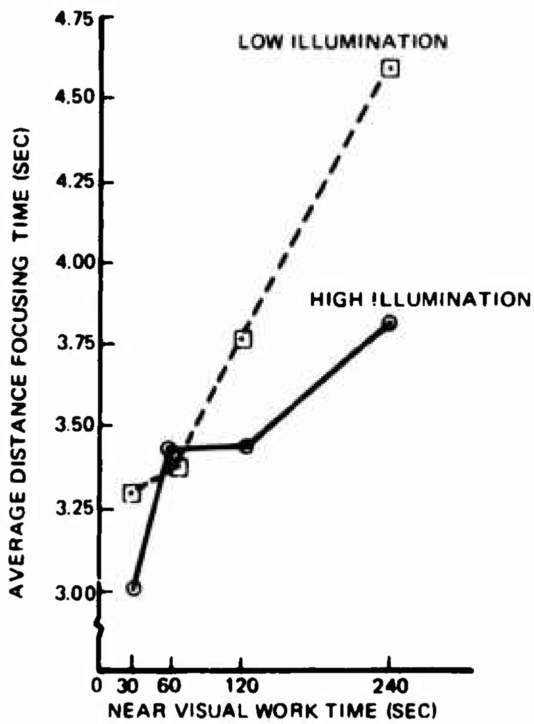


Figure 42: Effect of Illumination on Focusing Time (Near to Far)

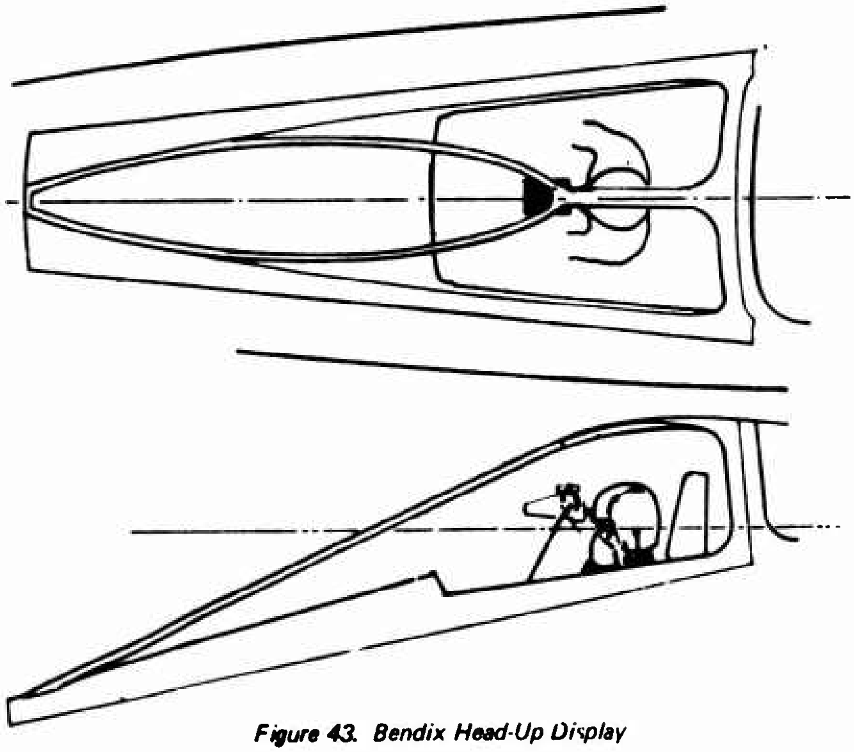


Figure 43. Bendix Head-Up Display

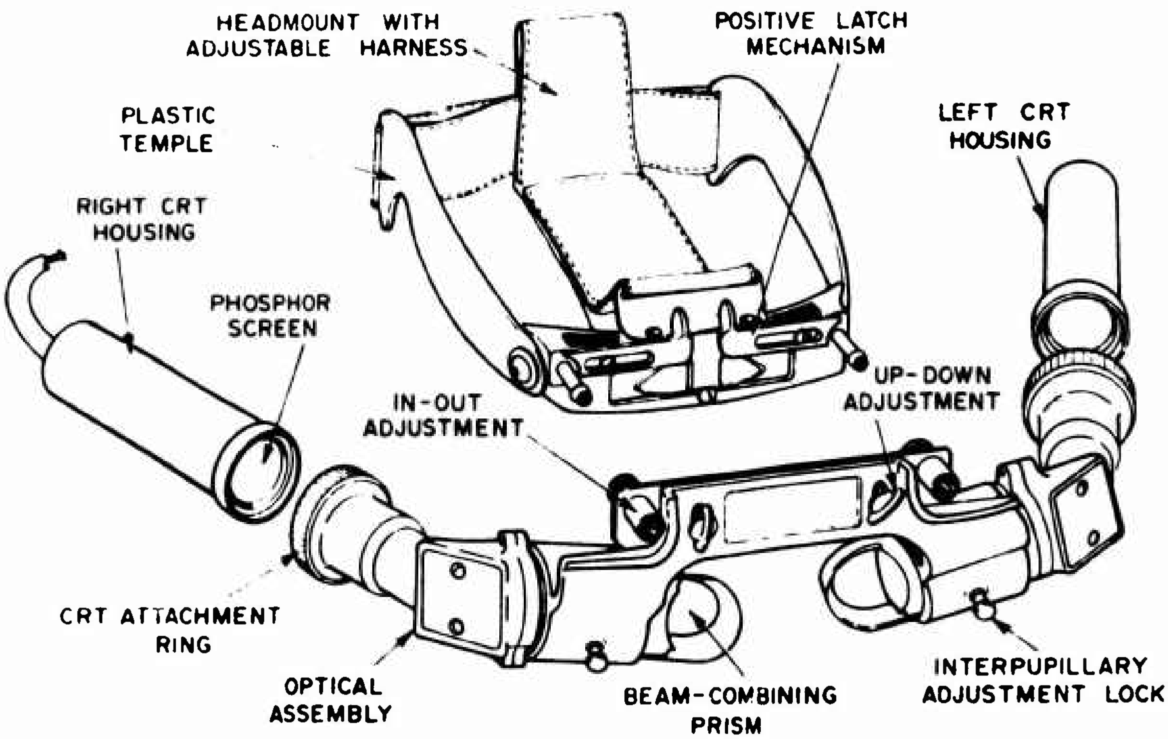


Figure 44. Perkin Elmer Head-Up Display

but requires that the pilot's head position be known so that meaningful information can be displayed. A combination of a helmet position sensor and a helmet-mounted display appears promising.

Another potential HUD configuration would attach the electro-visual transducer and the necessary optics to the canopy frame above the pilot's head. The combining glass would be placed in the pilot's line of vision and attached to the canopy frame (Figure 45).

Data presented to the pilot duplicate those presented on the VSD, with the exception of the TV presentation. The controls for the VSD also select the data for the HUD. To temporarily deactivate the HUD, the master intensity control on the level control is used to reduce the presentation intensity.

The HUD configuration selected for the IIPACS provides total field of view of 20° vertically and 25° horizontally. The combining glass folds down out of the pilot's vision when not in use. Liquid crystals provide a means for opaquing selective portions to accommodate TV presentations projected to infinity (Figure 46).

(b) Vertical Situation Display (VSD)

The VSD is a 1024-line, direct-view color cathode ray tube that presents information of flight situation, control, and weapon delivery in an integrated form using a TV raster technique. The tube has sufficient light output to be visible under ambient light conditions encountered in flight.

Data presented include color symbology representing pitch, roll, heading, energy management commands, flight cues, and tactical information necessary for performance of a complete mission under instrument conditions.

(c) Horizontal Situation Display (HSD)

The HSD selectively combines a cathode ray tube display with a colored moving map. The display provides present position, en route, target, and terminal information as the situation dictates. The display unit uses a combination of full color moving map data and ground-mapping data from the forward-looking radar, weapons delivery information for air-to-air guidance, and threat warning from the RHAW equipment, depending on pilot selections and flight mode.

The map display can be derived from the computer memory full color. The map is automatically positioned by the navigation system. A chart slew switch permits the operator to slew the map in any direction to

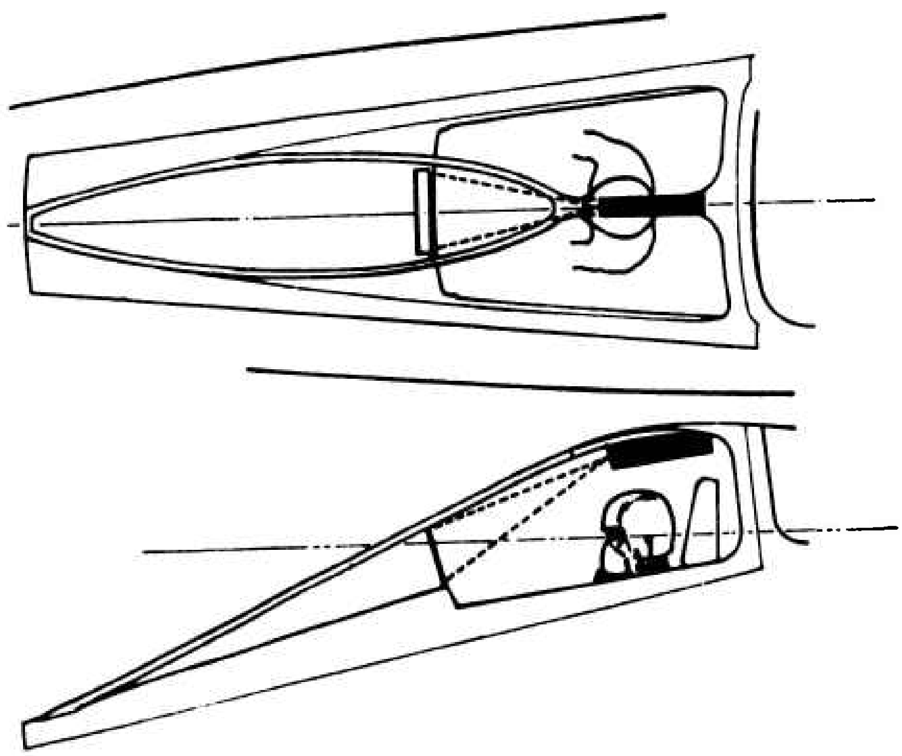


Figure 45. Potential Head-Up Display Configuration

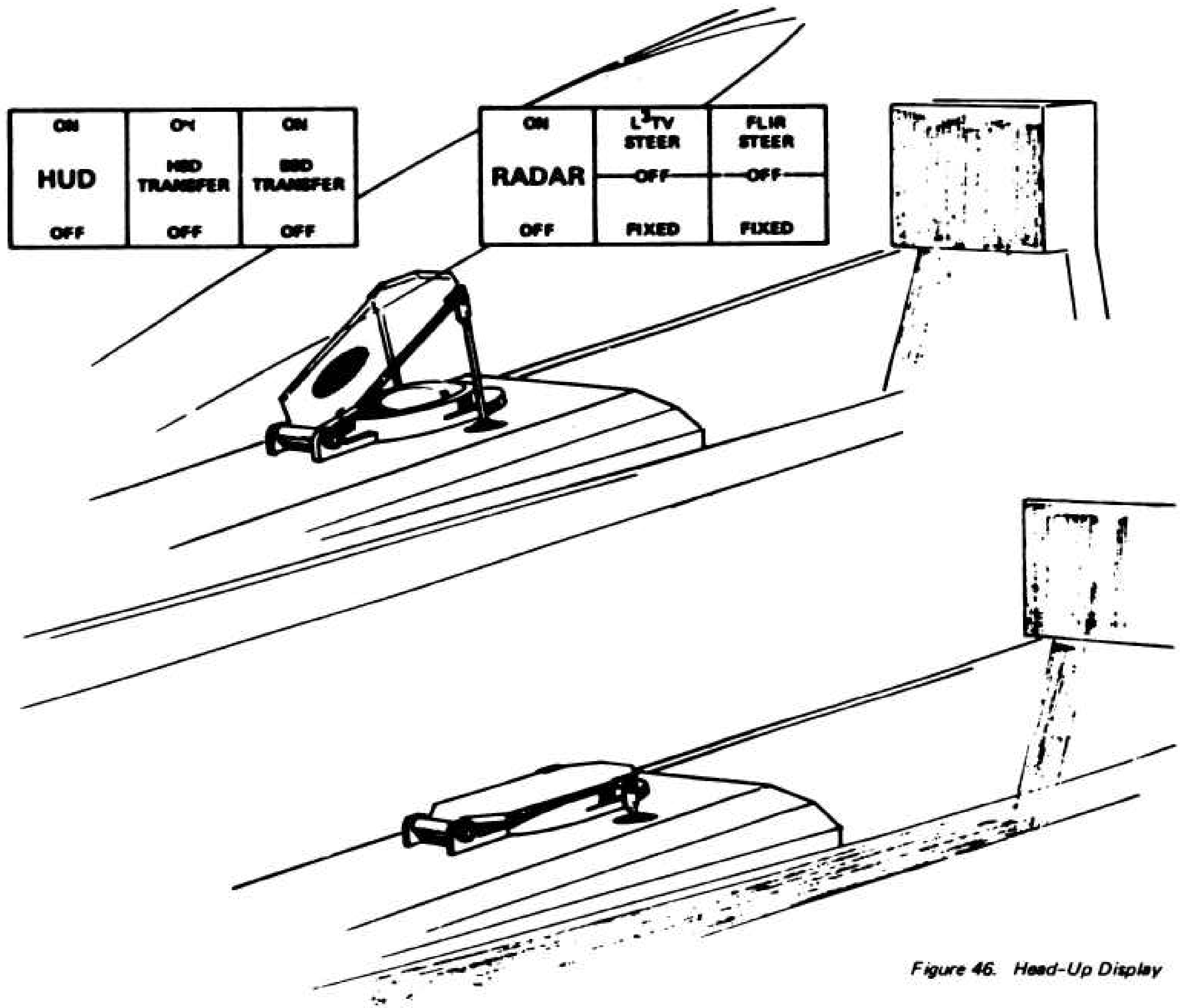


Figure 46. Head-Up Display

look ahead, but the map always returns to the present position when the switch is released. The map may be oriented with aircraft heading or north at the top of the display, depending on pilot selection.

(2) Multipurpose Displays (MPD's)

MPD's are time-shared presentations that display information supplemental to all normal flight phases but may be essential to airplane operation during emergencies. Typical information shown on these displays includes engine, navigation, altitude/airspeed, etc. These displays are selected on a preprogrammed basis, either as a part of the flight phase selection or by the use of special controls. VSD and HSD presentations must be transferable to one or more of these displays if a primary display fails. These displays receive their information over multiplexed lines from the computer complex.

(3) Secondary Controls/Displays

These panels provide information for special functions and for less critical items that should be available to the pilot on a continuous basis. The functions include fuel display and management and weapons selection and location display. These panels combine controls and displays and can use a varied group of control and display techniques, including plasma and electroluminescent presentations.

(4) Primary Controls

Primary controls form an interface between the pilot and the airplane that is essential to system survival and mission accomplishment. The analysis placed the following manual control tasks in the primary category:

- Control of roll, pitch, and yaw
- Control of roll and pitch trim
- Ground steering
- Automatic flight control system disconnect
- Braking
- Thrust reverser
- Target designation
- Gun firing
- Weapon release

The three cockpit configurations selected for evaluation differed mainly in the location of the primary flight controls. Trade studies selected only one control type for each manual control task. These selected controls were used in the wraparound cockpit configuration. Alternate controls were used in the other two configurations.

The shape of the flight control handles is shown in Figures 47 through 49. In each case, the functions of roll and pitch trim and manual weapon release are included in the control configuration, as are other miscellaneous tasks that conventionally are placed on the "stick." On the ground, the anti-skid wheel brakes are actuated when the pitch control stick is placed in the full nose-down position.

The tasks of yaw control and ground steering were assigned to the rudder pedals. Three-axis control sticks were examined but were considered unnecessary and excessively complex.

The task of target designation by the pilot is important. It is a manual operation for both the air-to-ground and air-to-air situations, especially when multiple targets are present. For these conditions, a three-axis designation (elevation, azimuth, range) control is provided.

(5) Secondary Controls

Secondary controls are important, but less critical, to flight safety or to the mission completion. Secondary controls include those needed to select display formats, radar modes, autopilot modes, weapons, etc. Trade studies resulted in the selection of each control. In some instances, the process of defining the control panels caused a second iteration of the analysis process to add necessary controls; for example, sensor mode selections were called for, but there was no callout of a range selection task. This had to be added when the control panel was designed that combined radar controls with those for the horizontal map display. The ranges on the two had to correspond, and a selection was necessary to make the map usable for low-altitude attack and landing as well as high-altitude navigation.

(6) Tertiary Controls

Tertiary controls are relatively unimportant to flight safety or to the mission. Examples of these controls are the APU and the ECS.

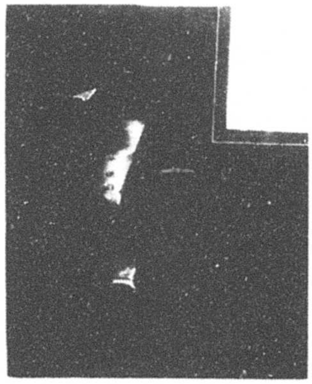


Figure 47. Panel Mounted Controllers

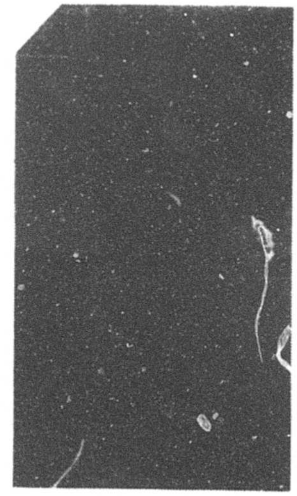


Figure 48. Side Arm Control

Figure 49. Center Stick

c. Displays

Three display levels are used in configuring these conceptual cockpits. Primary displays are the VSD, HUD, and HSD. These three display levels are placed in the primary vision area. A secondary display group, referred to as MPD's, performs various display functions for the pilot depending on the flight phase. These displays are located in the primary vision area. The third display level is that associated with the controls. These displays are located in the secondary and tertiary vision areas.

The primary and secondary displays use cathode ray tubes (CRTs) or an equivalent display media. In the projected time period, changes in CRT technology and the addition of new display devices should produce the capability to exhibit data to the pilot in bright sunlight or in the absence of ambient light with high reliability and at moderate cost. The work underway to produce shorter, ruggedized CRTs that have high brightness and can be seen under high ambient light conditions is well documented. Other developments in or emerging from the laboratories include light emitting diodes, plasma displays, and liquid crystals. Electroluminescence (EL) is current state of the art. Westinghouse has demonstrated and tested EL under high ambient light conditions. The use of color to enhance displayed data and to call the pilot's attention to specific information is considered feasible. A representative group of display formats is discussed below. Those formats selected show the versatility that may be expected from the system.

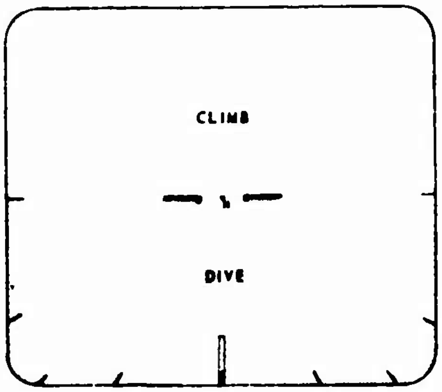
(1) Primary Displays

(a) Vertical Situation Display (VSD)

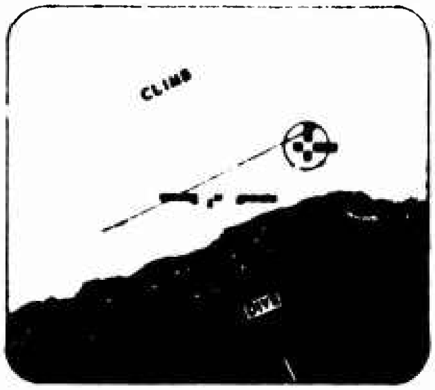
The VSD is the primary attitude reference. In presenting attitude data to the pilot, other optional information can be added to the VSD without cluttering it beyond the pilot's capability to note changes. These data are used for terrain following, target acquisition, and target attack. Presentation of computer-developed commands and total emergy management advisory data allow the pilot to fly manually.

The basic attitude display is an elementary version of an electronic attitude indicator. The presentation includes an airplane symbol, roll index, roll attitude, yaw deflection bug, and a pitch reference in the form of a horizon. For normal flight monitoring, this minimum display is sufficient.

This basic format is used in all VSD modes. Commands are those developed by the computer in its calculations for integrated total energy management. The display format used is described in the next paragraph.



A shades-of-gray or a color coded format is provided for terrain following. Four terrain profiles are presented, with gates at 1/2, 1, 4, and 8 nmi, with the vertical bars representing the 1-nmi profile. The aircraft symbol indicates that the aircraft is in a dive as may be seen from its relationship to the horizon bar. Yaw is indicated by the double vertical bars near the center of the aircraft symbol. The energy control director (ECD) may be seen to the right pointing the path through a saddleback on the horizon. With an automatic tie-in such a discrepancy in aircraft position with respect to the ECD would not exist; however, a hypothetical case was established for the illustration. The squares to the left and bottom of the center of the ECD are sized and shaped to the "on flight path" configuration. The rectangle elongated from the basic square above indicates the nose-up command. The rate of elongation to the desired pitch angle is mechanized to conserve energy by programming the ideal-g schedule to the optimum angle of attack for climb under the given conditions. Simultaneously, the rectangle on the right similarly through the rate of elongation indicates ideal roll rate to the desired bank angle to minimize energy loss due to adverse yaw at that specific angle of attack and drag due to control deflection. It programs the bank angle, again in deference to normal acceleration. The circle directs energy requirements along the longitudinal axis. Since altitude represents a form of energy and the mass and drag of the aircraft is known, it may be exchanged for thrust independently or with the throttle directly affecting the circle's behavior. When longitudinal energy requirements are met, the circle is contiguous to the outer tips of the squares. Since a command pitch up and pitch down or turn left and turn right will not occur simultaneously, two of the command indicators will always be squares. A larger than "on energy level" circle commands an increase; conversely, a smaller circle commands a decrease in longitudinal energy.



ITEMS has been designed to degrade gracefully from a highly automatic control/display system to a rudimentary system of displaying only that raw data necessary to survival.

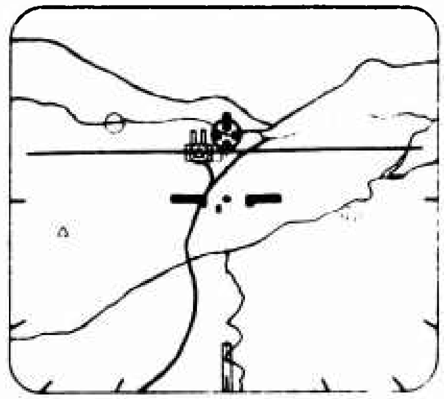
Certain displays are available to the pilot on demand. For whatever reason he chooses, the pilot can call forth these displays on any MPD. This is done with the keyboard control. By selecting ITEMS from the major systems available in the Master Keyboard Select row, the following energy management display formats may be inserted into any MPD, the VSD, the HUD, and/or the HSD:

- Air Data and Thrust
- Vn Envelope
- Climb Profile
- Thrust Required/Thrust Available
- Engines
- Landing Monitor

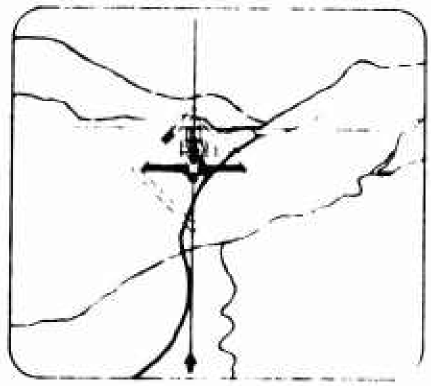
Heading, angle of attack, flight vector, pitch and roll, and command information may be added to any display depicting the vertical situation. Heading, distance, or range may be added to any display depicting the horizontal situation.

The pilot can select any combination of fixed and steerable TV, radar, and FLIR target acquisition sensors. The television sensor is used as the primary VSD presentation during visual target acquisition. The TV presentation is in color for daytime operation; it is black and white at night. TV and FLIR are azimuth and elevation sensors; however, by synchronizing all sensors to a common line of sight, a third dimension range is provided. If the three sensors are chosen, their returns are superimposed, provided the target produces returns in the RF, IR, and visual spectra. A target designation cursor is placed on the target manually, the designation button is used, and the computer uses the selected sensors to track the target.

In this illustration, a power house is the preplanned target. The circle represents radar returns, the triangle represents IR returns. The pilot is manually controlling the airplane in pitch as the ECD is high with respect to the airplane symbol. A pitch up maneuver is being called for to counter the dive which is being used to get a better view of the target. The pilot has not yet designated the target. If he had, the ECD would be calling for a small turn to the left, and the remaining radar and IR symbology would have been removed. The target designation cursor is in view only during the designation process.



After target designation, the final attack sequence begins. When the target nears the outer release envelope of the selected weapon, a fire control symbol appears. The energy management symbol is retained. The movement of the dot on the fire control symbol represents qualitative range rate. It appears at the 11 o'clock position and moves counterclockwise. The 6 o'clock position represents the maximum effective range for the selected weapon, and the 12 o'clock position is the minimum effective or safe firing range. The computer continually updates weapon release parameters; therefore, weapons are dispensed automatically when the dot is at the 3 o'clock position and manually when the dot is between the 6 and 12 o'clock positions. The fire control symbol is also used as an approximate aiming window or reticle. For steerable weapons (Walleye, Bullpup), the size increases with decreasing range to compensate for the weapon maneuver reduction as the target is approached. Nonsteerable weapons require the same aiming accuracy throughout their release envelope; therefore, the fire control symbol is fixed in size for these weapons. Breakaway is represented by a large X on the display.



The weapons on board may be programmed sequentially for use on a single target in a descending order of the weapon's maximum release or firing envelope. In the case of overlapping envelopes, fire control information is

dedicated to the maximum range weapon unless the pilot overrides it. When minimum range of the weapon is reached or when the weapon is dispensed, the fire control information for the next weapon in succession is displayed. In addition, the system has a multiple targeting capability.

(b) Head-Up Display (HUD)

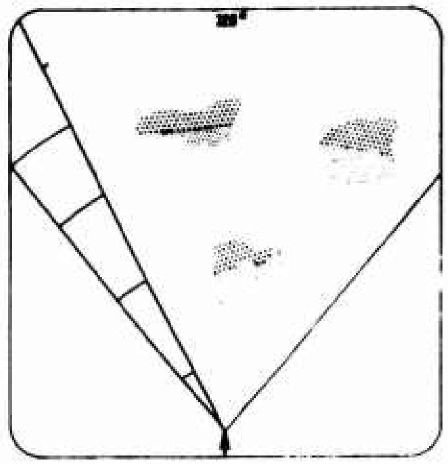
The HUD presents information identical to that presented on the VSD, with the exception of TV. (Steerable TV only is presented on HUD.) The total energy management bug gives the pilot complete information for all flight conditions. Control functions applicable to the VSD produce corresponding changes on the HUD. HUD brightness may be reduced to zero by means of the level control panel.

(c) Horizontal Situation Display (HSD)

The HSD is the main source of heading and position information. The information sources feeding the display are the navigation system, the multimode radar, and the passive identification system. A moving map can be displayed in all modes. Radar PPI data is selectable. VSD terrain following information is augmented by a terrain clearance PPI presentation (situation display) on the HSD.

To provide supplementary information to the pilot, a moving map may be presented on the HSD alone or in c n-junction with any range-azimuth information available to the system. The moving map is synchronously slaved to the navigation sensors via computer inputs.

The air-to-ground radar mode on the HSD has four representations: (1) conventional PPI, (2) terrain avoidance "situation" display, (3) a selectable 1 x 1 or 2 x 2 NM "snapshot" presentation about the crosshair, and (4) a 1, 2 or 4 NM swath width presented as a "passing scene" during SQUINT mode. To give the pilot more anticipatory information, the airplane symbol may be presented at the bottom of the display when in OFF CENTER SECTOR (OCS). The HSD presentation is a valuable adjunct to the VSD when using the radar as a target location device. For a preselected target along ground track with known coordinates, the target designation cursor appears automatically at the top of the screen over the predicted map location as that location comes within range. The



computer, using data on the circular error probability of the selected navigation sensors, processes the radar returns to eliminate all those extraneous returns that lie outside this circle.

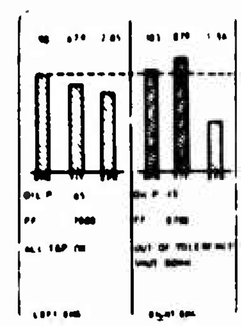
Moving maps will be scaled to the selectable display ranges. Detail maps will be available for takeoff and landing. Display brightness and contrast are controlled by the level control.

(2) Multipurpose Displays (MPD's)

MPD's are grouped around the VSD and HSD. They present more vital information in the available primary space than is possible with conventional instrumentation. Graphic and alphanumeric information in color is tailored to the flight phase and provides the pilot with comparative data for increased confidence in system operation.

MPD presentations can be manually or automatically selected. Manual selection is made by using the preprogrammed selector switches on the display. Automatic selection is provided when a serious malfunction occurs or a flight mode change causes a selected display to be superseded. A general malfunction presentation appears if no special purpose display is provided. In either case, the failure display does not replace a presentation that is essential to the current flight phase. As indicated above, the presentations can be called up on one of several possible MPD's located at different places on the instrument panel, depending on the configuration. For this reason, the presentations discussed below do not define presentation location.

(a) Engine Instrumentation

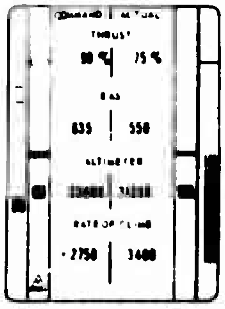


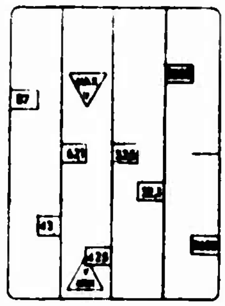
The pilot checks on his engine performance by scanning the bargraphs. These graphs are designed so that all limitations are at the same level. Thus the limit line is a straight line across the presentation. The numeric value corresponding to the height of the bar is shown at the top of the bargraph.

Below the bars are other data legends defining the bargraph parameter and action required.

(b) Thrust/Airspeed/Altitude/Altitude Rate

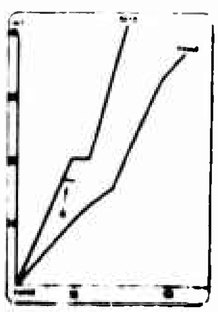
The presentation is a backup for the total energy management command symbol on the VSD. Two versions of the thrust/airspeed/altitude/altitude rate presentations have been designed. Both show the same data in different ways. The first uses alphanumerics extensively to reinforce a vertical tape type display. The left-hand bar is the thrust display with the commanded thrust shown as two horizontal lines and the actual value as an opaque square. When "On Command", the opaque square is centered exactly between the "Command" horizontal lines. The next bar to the right is the airspeed presentation with the triangles depicting upper and lower speed limits for the altitude condition. The central line is the commanded airspeed, the cross-hatched square is the actual airspeed. When "On Command", the bar rests on top of the square. Of the two right-hand tapes, the left one is the altimeter with the command bar and actual altitude square. "On Command" indication is the same as in airspeed. The altitude rate is shown by the right tape. The command is shown as the horizontal bar. The vertical bars working from a center scale reference represent the actual reading. The second format places the command and the actual numeric values within the confines of the symbol used, the command value on the left and the actual on the right. In each instance, the "On Command" indication is represented by alignment of the command and actual boxes.

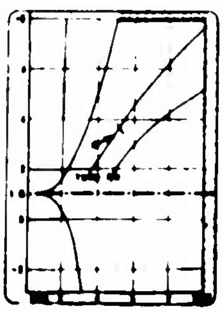


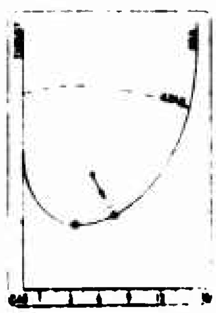


(c) Energy Management

Three supplemental display formats that augment the ECD may be selected. They provide the

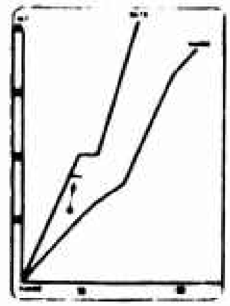






pilot with system confidence type information during the ECD-directed flight phases. The displays shown provide predictibe energy management information when the ECD is not directing the system or when the VSD is disabled. The use of these presentations is described in detail.

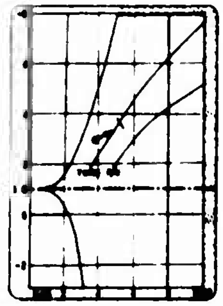
The energy management display format that is most useful during climb conditions presents altitude on the Y axis and range on the X axis. The curve labeled RATE is followed to obtain a minimum time climb to a predetermined position. The curve labeled RANGE is used to fly to a maximum range climb profile. The curve presented depends on the selected flight mode. The dot and arrow indicate present position, magnitude, and direction of motion. This presentation may be monitored during automatic flight. In manual flight the pilot may use the presentation to guide him in controlling the airplane.



The RATE curve applies primarily to the interceptor-type mission; however, it may be used by the tactical fighter pilot to make an emergency evacuation from his base or during a dogfight to make a maximum rate climb. The RANGE curve is used during any maximum range altitude change. The RANGE curve is used during any maximum range interdiction missions or return to altitude after terrain following.

These dynamic, computer-generated curves depend on the changing input data. These data inputs include such parameters as static pressure, dynamic pressure, angle of attack, navigation waypoints (range), air temperature, throttle position, attitude, etc. In manual flight the pilot uses pitch control plus throttle position to follow the maximum RANGE curve, while pitch alone is used to follow the maximum rate curve since the throttle would be in full afterburner position. The dot shown in the illustration represents present airplane position in altitude-range space. The arrow indicates the motion vector. As is the case for all vectors, it represents direction and magnitude with respect to a reference. For illustration, the airplane has been placed above the RANGE line, indicating too much altitude, and the vector is shown extending beyond the bar, indicating too much thrust (throttle setting for the particular pitch condition).

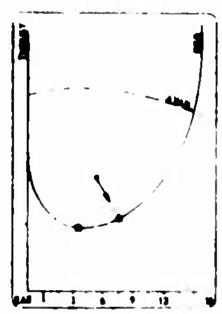
The velocity-load factor (V-n) diagram is used to determine whether the airplane is approaching an unsafe flight condition for the current airplane configuration and load conditions. Reference to this diagrammatic presentation relieves him of having to make a mental approximation of his relative position with respect to the limits. He knows where he is and, thus, can push his airplane to the safe limits and obtain maximum performance from it.



The boundaries of the V-n diagram change to reflect the changing conditions of flight. The conditions are airplane gross weight, external configuration, load symmetry, and air turbulence. The external configuration affects the stall boundary as well as the load limits. For example, the g-loads that the airplane can safely experience in normal flight are off limits when the flaps are extended. Also, wing sweep changes the stall and limit boundaries.

The illustration shows the airplane, represented by the dot, at a speed of 360 knots estimated air speed (EAS) and a load factor of 2.9. The arrow on the dot indicates that speed and n are both increasing. The straight and level steady-state flight condition would find the dot on the 1-g line resting at the measured EAS. Excursions from this position would be evidenced first by the extension of the arrow from the dot. Throttle position change without changing pitch angle shows up as a change in n, while pitch changes will affect both n and EAS.

The THRUST-EAS (thrust available-thrust required) curve presents information needed to obtain maximum range or endurance flight or to properly control the airplane during landing or degraded mode engine-out conditions. Two curves are presented: one indicates the total available thrust that can be called for from the two engines with full afterburner for a given altitude and airspeed; the second shows the thrust required to maintain an airspeed for the existing conditions. The location for the airplane on this dynamically varying curve is indicated by the circle with the cross in the center. Two additional points on the curve are presented. The triangle indicates the thrust-airspeed condition required to obtain maximum

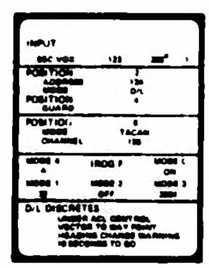


range from the airplane. The square has two functions: to indicate the maximum endurance condition, and to delineate the point at which the airplane controls reverse their effect. This effect is discussed in more detail below.

These curves are affected by various factors. Available thrust is changed by altitude (air density) and aircraft velocity. Required thrust is affected by gross weight, airplane configuration (flaps, wing sweep, landing gear), and airplane maneuvers. Because of the dynamics of the situation, it may not be feasible to generate this curve in real time for rapidly changing air-to-air combat maneuver conditions. These curves are useful in establishing the flight conditions needed for maximum endurance or maximum range flight, or in monitoring the airplane performance during landing where the airplane may be flown at speeds below the reversal point.

The characteristics of steady-state flight in the region of normal command (to the right of the square) are that lift is equal to weight and the power used is set equal to the power required. When the airplane is disturbed to some slightly greater airspeed, an excess of power exists and, when the airplane is disturbed to some slightly lower airspeed, a deficiency of power exists. This relationship is basically unstable because the variation of excess power to either side of the point tends to magnify the original disturbance. Flight in the region of reversed command is characterized by a relatively weak tendency of the airplane to maintain the trim speed naturally. In fact, it is likely that the airplane will exhibit no inherent tendency to maintain the trim speed in this regime of flight. For this reason, the pilot must give particular attention to precise control of speed when operating at reversed command speeds.

(d) Communication/Identification (C&I)

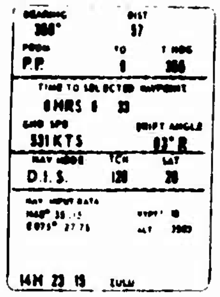


The control selections made on the C&I panel and data received by the data link or from the voice input are presented on this display. Incoming data link messages are indicated in the lower box along with the time-to-go target.

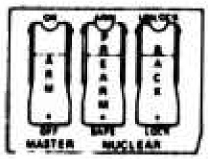
(e) Navigation

The drawing shows typical navigation information available to the pilot. Most of the items are

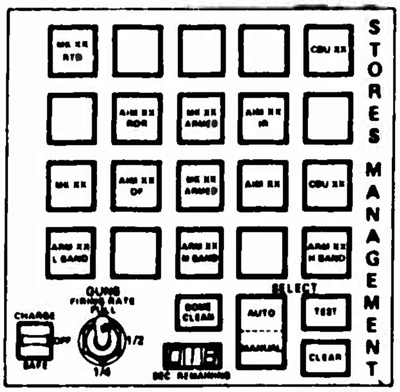
self-explanatory, with the exception of the items in the third box down. The navigation mode is shown in Doppler Inertial Satellite (DIS) mode. TACAN channel 126 is selected and the satellite channel is #26. The bottom box presents the information on the home base, the next waypoint, or the data being manually entered into the computer via the keyboard.



(f) Stores Management System (SMS)



The primary cockpit controls and displays associated with the SMS include: the stores management panel with its master arm and gun selectors; the coded switch selectors; the coded switch panel for nuclear consent; the MPD for presentation of stores release options; a conventional and, separately, a nuclear weapon jettison button; and the integrated keyboard control for preprogramming the operation or to conduct a program change in flight.



The SMS uses the computer complex to integrate weapon selection, control, monitoring, and release functions and to interface these functions efficiently with the rest of the avionics subsystem. The capability to carry and control mixed loads, including nuclear weapons, is emphasized. Display and sensor selection is integrated with stores control. The logic of the system is used to display only compatible options for the weapons selected, thus simplifying crew tasks and decreasing the chance for human error.

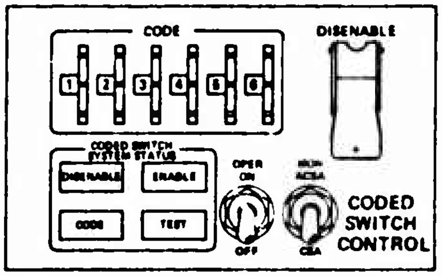
The Stores Management Control (SMC) Panel is a continuously available panel with quick access for monitoring and control of all on-board weapons. The SMC Panel continuously displays the store data on the back-lighted pushbuttons. The pushbuttons are used to select a weapon or station(s) for subsequent control through the integrated keyboard. A pushbutton, used for cleaning weapon electro-optical sensor domes, is included. For guns, Charge/Safe and Firing Rate switches are provided on the SMC Panel, as well as a Time Remaining Counter slaved to the firing rate switch. The Master Armament Switch controls all arming power to the SMS. A Mode Select

Switch allows the operator to select Auto, Manual, or Test modes of operation for the system. The Rack Lock and Prearm Switches are guarded and sealed toggles that provide the required nuclear weapon safety, and the recessed Jettison Switches provide the capability to quickly clean the airplane of conventional weapons (ALL) or to individually jettison nuclear weapons (SEL) that are in the SAFE condition.

Stores stations are flexible and can accommodate almost any weapon. Remote logic plugs are used to simplify computer programming and to prevent mistakes. Stores data are set during weapon loading into the remote logic plug (located at each station). This information is automatically transmitted to the computer and to the SMC Panel where it is displayed on the pushbutton identified with the weapon as weapon type number and status.

Arming and fuze selection is conducted while airborne for both nuclear and conventional weapons.

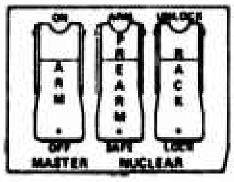
The coded switch system (CSS) replaces the PAL for nuclear weapons. The CSS will provide the same nuclear safety but will actually control arming power within the aircraft rather than the weapons. It may be deleted in a nuclear war. All weapons are at least partially preprogrammed for automatic delivery under normal operating conditions.



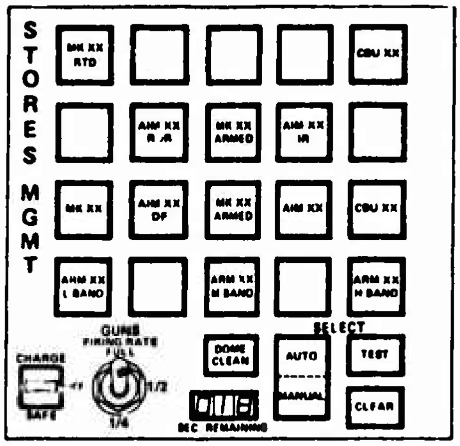
An automatic sequence is manually vetoed or overridden by pushing appropriate switches on the SMC Panel. This action sets up an MPD and integrated keyboard alphanumerics. By observing alternatives and following options presented on the MPD, the pilot can completely or partially reprogram weapon data. If the pilot makes a mistake, the system will not accept data but will, by means of the MPD, provide alphanumeric instructions to correct the error.

Degraded mode operation is provided with manual backup and complete manual delivery using an MPD and the integrated keyboard is possible. Manual operations are also included for improved flexibility and to allow for preengagement setups.

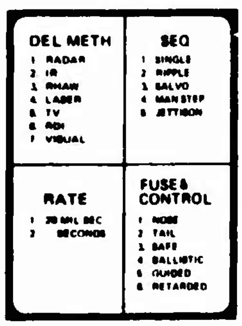
Automatic delivery using preprogrammed data or by data link is defined as the normal baseline delivery mode and does not require pilot decisions. The pilot is kept informed primarily with the SMC Panel. He can also monitor more detailed information with MPD's and the VSD. The integrated keyboard is not needed in automatic delivery except to switch and monitor displays.



The SMC Panel continuously displays the stores remaining and their locations on the airplane. A lighted pushbutton switch is provided on the panel for each store station. The switch is lighted white (blue, if nuclear) if a conventional store is loaded at that station. When a weapon or station is selected (automatically in this case), the switch light turns green and the stored program to be executed is presented on the MPD. Stores Away is indicated on the pushbutton by an amber light. A stores release signal without a stores-away signal will cause the affected pushbutton to turn red. The fire control diamond on the VSD/HUD will illuminate in colors corresponding to the pushbuttons status indication.



The pilot must always manually operate nuclear prearm and the coded switch system. When received over the secure communications data link, the command control code is manually inserted by the pilot through the six thumbwheel switches. The OPERATE switch is placed in the ON position to transmit the code to the Coded Switch Assembly (CSA). The CODE light illuminates to indicate that the CSA is cycling. and the DISENABLE light goes out. When the CSA cycling is complete and the proper code has been inserted, the ENABLE lamp is illuminated. Then the Auxiliary Coded Switch Assembly's (ACSA) status at each nuclear station



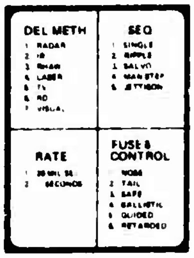
can be monitored by moving the CSA/ACSA switch to the ACSA position (Momentary). If any ACSA is in the enabled position, the ENABLE lamp will be illuminated again. If a sum check code has been inserted, the TEST lamp will illuminate at the end of the cycle, but the CSA will not be enabled. The DISENABLE switch, protected by a camming cover, provides the capability to disenable the controller after a system test.

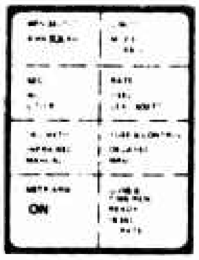
Separate on-board fire control sensors and navigation sensors are available for target location. Automatic or manual stores management may be selected. Twenty-weapon stations are available. Weapons may be released with or without the computer. A failed component and an acceptable substitute can be switched out and in either automatically or manually with the keyboard.

While in the automatic release mode, stores may be released manually by depressing the stores release button on the flight control stick prior to automatic release. Override of the automatic release mode may be affected by selecting "manual" on the SMS panel. Automatic mode may be reselected at will.

The integrated keyboard is used for program insertion and manual stores management. An associated MPD provides supervisory instructions. Alphanumerics for generalized weapon control are provided when the integrated keyboard SMS key is pressed.

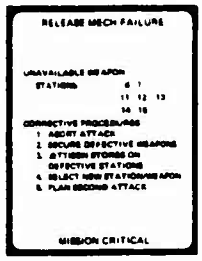
Options are selected or changed by typing the selected numerical option shown on the MPD. Options not selected are removed from the MPD. When the last applicable option has been selected or changed, the MPD provides a readout of all selections for the operator's review before insertion or initiation of the program. The unused options are removed from the MPD and will be presented again only upon command (SMS button). Selected options are automatically shown on the MPD when the delivery program for that weapon is initiated. The new program is inserted into memory with the ENTER button. The program for any weapon may be recalled with the station button on the SMC Panel (previously described).





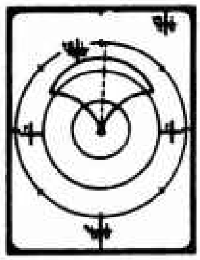
(g) Malfunction

A FMAC-detected malfunction is automatically placed on one of the MPD's that is not being used for flight or mission critical data. This presentation defines the malfunction in plain English and calls out the action to be taken. It also defines the limitations placed on the remainder of the flight by the malfunction.



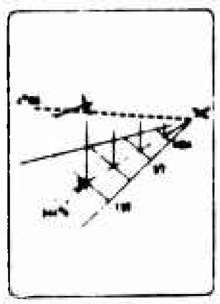
(h) Battle Situation

The BSD is developed from sensed enemy emissions in the RF and IR spectra. By receiving the energy while the tac' al fighter is moving, lines . be computed to the most probable location of the enemy emitter. Sorting techniques and memory comparisons allow the emitter type to be classified. These data are presented on a PPI-type display with the airplane centered. The alphanumerics define the threat type and location. For the #1 airborne threat, a line is projected to show the intercept point. The pilot has the option of selecting (through the keyboard) whether he wants to look at air, ground, or both types of threats and whether he wishes to have the alphanumerical information.



(i) Landing Monitor

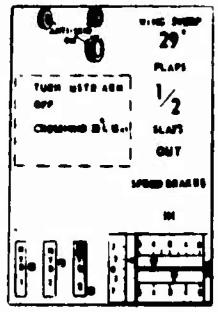
The landing monitor is intended as a backup for the main VSD/HSD landing displays. It is a three-dimensional, pictorial representation of the airplane position with respect to the runway. The dashed glide slope line, the dot representing the airplane, and its vector provide vertical alignment data. The line in proximith to the arrowhead denotes desired length. The extension of the runway centerline is identified along with its magnetic heading. A second airplane location circle is shown on the horizontal plane along with its vector. The alignment of both vectors with their respective correct paths is the desired condition.



(3) Secondary Displays

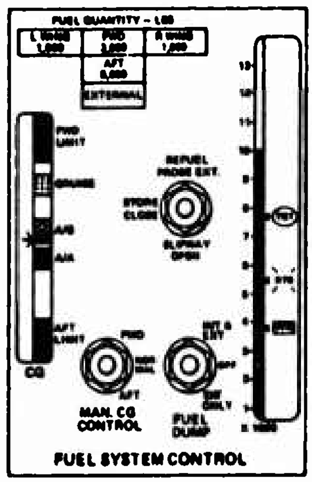
This group of displays was assigned to secondary viewing areas as a result of the analysis. With the exception of the fuel display, these presentations are used during limited portions of the flight.

(a) General Purpose Display (MPD-5)



This presentation indicates position of landing gear, wings, flaps, slats, and speed brakes. Other information includes the amount of trim being used, hydraulic system pressure, and an alphanumeric advisory readout. To denote landing gear position, the words "UP" and "DOWN" appear at the appropriate gear locations.

(b) Fuel Management Panel



Aircraft cg is controlled by the central computer complex (CCC). Flight mode is selected on the flight mode selector. Appropriate cg range per selected mode is activated, thus sensing desired cg range. Cg based on fuel distribution is computed from fuel quantity sensed in each fuel tank. CCC controls transfer of fuel from forward or aft tanks as required to shift the cg in response to the flight mode selected. Wing and external fuel is transferred automatically to the fuselage cells as necessary to maintain fuselage fuel level at the most practical level to provide for the extreme fore and aft shift of the cg. Wing tanks are segmented so that fuel transfer is from the in-board sections first.

Fuel quantity is sensed by radioactive sensors and converted to usable signals for application to the cg control as well as for digital readout of quantity for the pilot. Fuel quantity in each tank and the total quantity are presented in digital format on the fuel control panel.

Total fuel on board is also presented on a vertical bargraph display. Three moving symbols are used to signify fuel requirements for each mission programmed. Navigation and total energy management system inputs are integrated by the computer to position each of the symbols with respect to the fuel required. The target (TGT) symbol represents the quantity of fuel remaining on arrival at the target if the preplanned route is followed. Return to base (RTB) symbol is positioned opposite the fuel remaining if the pilot elects to return to base at the most economical cruise via a direct route, and PPR symbol shows fuel remaining if the preplanned route and speed schedule is followed for the entire mission. Mission fuel is represented in green on the bargraph, and the reserve fuel is shown as amber. Changes in mission route planning and/or changes in power requirements will be presented as changes in fuel required on the bargraph.

In-flight refueling (IFR) may be accomplished either with boom-type or probe- and droge-type refueling. Actuation of the IFR switch to Probe extend will cause the refuel probe to extend and the system valving to be positioned for receiving fuel from the tanker. Actuation to the "slipway open" position opens the slipway doors in preparation for boom-type refueling. The "Store" close position sends a retract/close signal to the system used during refueling. Refueling automatically sequences fuel to each tank as required including external tanks as desired, when selected on the integrated keyboard.

Fuel may be dumped selectively either "external" or "internal and external" as required. Selection of "internal and external" position will reduce the fuel quantity to maximum landing weight in less than 5 minutes.

FMACS senses a failure of the automatic cg control. Cg presentation and flight mode cg range are unimpaired. Signal to the pilot is presented visually and by voice. The computer triggered by the failure signal presents information on an MPD to the pilot providing the alternatives available.

Alternative 1:

> CCC will use alternate paths as required. This may be by computing control surface displacement and forces to determine cg. No pilot action is required.

Alternate 2:

CCC will measure and maintain fuel quantity ratio between forward and aft tanks. No pilot action is required.

Alternate 3:

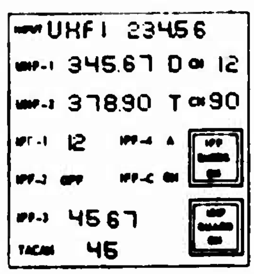
If computer is unable to perform either of the above, manually control fuel distribution to maintain cg in selected flight mode range.

Other type failures which may occur are:

	Failure	Corrective Action
(1)	Boost pump failure	Automatic crossfeed
(2)	Wing fuel transfer - pump failure	1. Transfer fuel from one wing and dump fuel that cannot be transferred. 2. Pressurize both wing tanks and force fuel to fuselage tanks. This bypasses pumps.
(3)	Fuel quantity digital readout failure	1. Bargraph presents total. 2. Instruct CCC to give tankage fuel quantity.
(4)	IFR probe failure	Switch to boom-type refuel.
(5)	IFR slipway failure	Switch to probe/drogue type refuel.
(6)	TGT RTB PPP function failure	Instruction computer to provide fuel requirements for desired information; update as required.

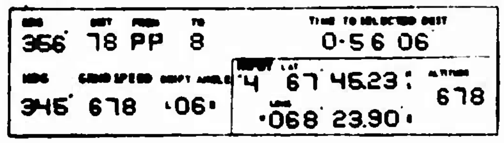
(c) Communications

This panel, used in the centerstick configuration, uses light emitting diodes (LEDs) to indicate the selected communication and identification modes.



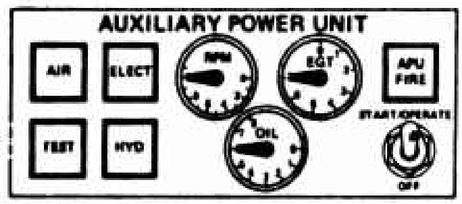
(d) Navigation

Used in the centerstick configuration, this navigation status panel uses LEDs to indicate the navigation selections and relative position of the flight. The information presented is in terms the pilot can most readily use, namely range, bearing, and time. Other pertinent information includes waypoint and a latitude-longitude readout.



(e) Auxiliary Power Unit (APU)

To give the tactical fighter an engine starting capability, an on-board APU is provided. This panel has all the displays and controls to make the APU a completely independent unit. It is one of the few hard wired units in the airplane for it must operate when the main alternators are inoperative. It has its own group of instruments and fire indication. If an APU fire occurs during start-up, the APU fire button is depressed to activate the extinguisher and shut down the system.



d. Controls

(1) Primary Controls

This section discusses the selection and grouping of the primary controls. The primary controls are those that the pilot must use to control the airplane manually and to designate his identified target.

(a) Control Stick

The three conceptual cockpit designs resulting from the IIPACS program differ primarily in the type of control stick used. The advanced wraparound cockpit has a sidearm stick, the intermediate cockpit features brolly handle control, while the more conventional cockpit has a centerstick. While airborne, the control stick is the roll and pitch interface between the pilot and the airplane. On the ground, the control stick actuates the anti-skid braking system. Each stick design includes the capability to control the auxiliary functions of pitch and roll trim, nosewheel steer activation, stores release, gun trigger, and autopilot disconnect.

Human engineering techniques were used to position the stick in a location comfortable for the pilot and to shape the stick so that it fits his hand. In each configuration, provision is made to give the pilot the capability to fly the airplane using his left hand.

The panel mounted control handles are displacement-type controls. The center and sidearm sticks could be either displacement- or force-type controls. Either type of control is compatible with fly-by-wire and variable stability controls that are considered desirable for this airplane system.

The wraparound cockpit has a sidearm stick located at the forward end of the right armrest. It uses the conventional stick operations of fore and aft for pitch and sideways for roll. The armrest location gives the pilot excellent support for his arm during high-g pullup maneuvers. Left-hand operation of the control stick is awkward and uncomfortable.

The wraparound sidearm flight controller was updated to reflect the results of the hand controller study (Ref. 5). The controller, Figure 50, uses conventional operations to control pitch and roll. The designation control provides an alternate (left- or right-hand) means for flight control.

The two panel-mounted control handles (Figure 5) are located just forward of the armrests and extend from the instrument panel. Pitch control is obtained by moving the handles fore and aft, roll by rotating them. The mechanical design of the rotational mechanism plus the method of mounting the handles use the capability of the forearm to rotate as a whole about the elbow joint. The fixed vertical position takes advantage of the small variation in eye to elbow distances between the 5th and the 95th percentile man. This displacement-type control normally makes use of the two hands; no backup control is needed if one arm is incapacitated.

The centerstick (Figure 4) is an adaptation of the conventional control stick and is designed to be comfortable for use by either hand. Being equally accessible to either hand, no backup control stick is required.

(b) Rudder Pedals

The rudder pedals are used for both rudder control and nosewheel steering. Nosewheel steering is disconnected when the oleo is extended.

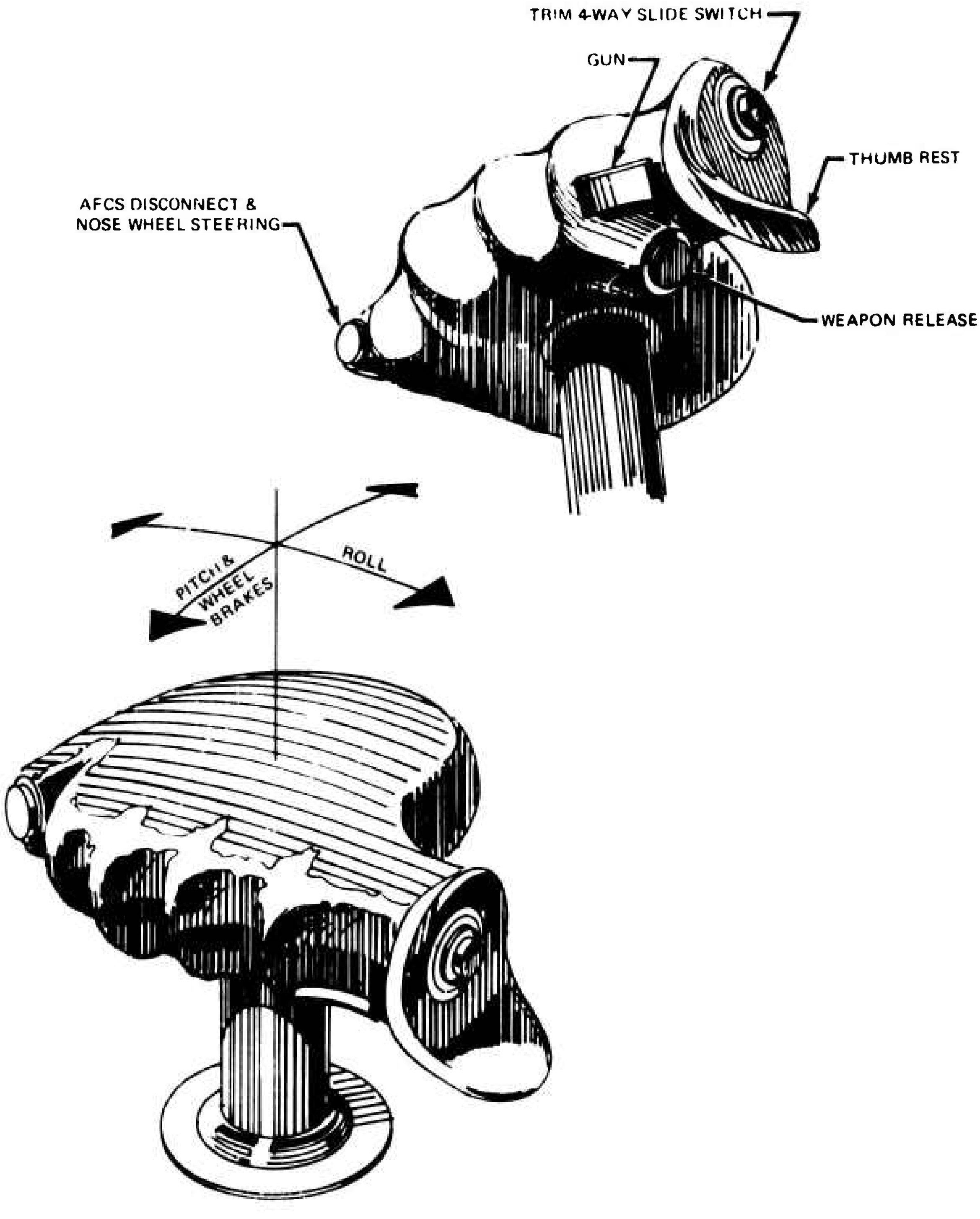


Figure 50. Flight Controller

(c) Throttle

Each cockpit has a different throttle concept. Each configuration has a separate engine control panel that is used to start and trim the two engines. Located on each of the throttles is the push to talk buttons the pilot uses when he wishes to transmit a voice message. All the throttle concepts are compatible with the multiplex fly-by-wire concept.

The brolly-configured cockpit has dual throttles, one for each engine, located on the left console. Thrust is increased by a linear displacement motion down and forward. Afterburner is engaged by forcing the throttles beyond a detent.

The throttle on the centerstick configuration is located on the left movable armrest. It is a force control and operates with a clockwise force to increase thrust and a counterclockwise force to decrease thrust.

The throttle for the wraparound cockpit is a vertical handle extending up from the horizontal lap console surface. It is a rotary force control; that is, exerting a clockwise force on the control will cause the engines to increase thrust and a counterclockwise force will decrease thrust. The single control output is transmitted to both engines. To go into afterburner, the pilot is required to exert an even higher clockwise force than that required for a normal thrust increase.

The throttle controller for IIPACS-2, for the flight controller, was updated in accord with Ref. 5. A single throttle is used for both engines. Engines are synchronized automatically; however, manual engine trim controls are located on the master engine control panel for manual operations.

Thrust reversal is controlled by pressing the thrust reverser bar switch, Figure 51, and rotating the throttle grip to the desired setting. Release of the enable bar holds the grip in the set position. Using the enable bar and rotating the grip to the down position or manually overpowering the holding device, provides forward thrust.

The microphone switch is a two-position control: forward for normal communications, aft for voice commands to the computer.

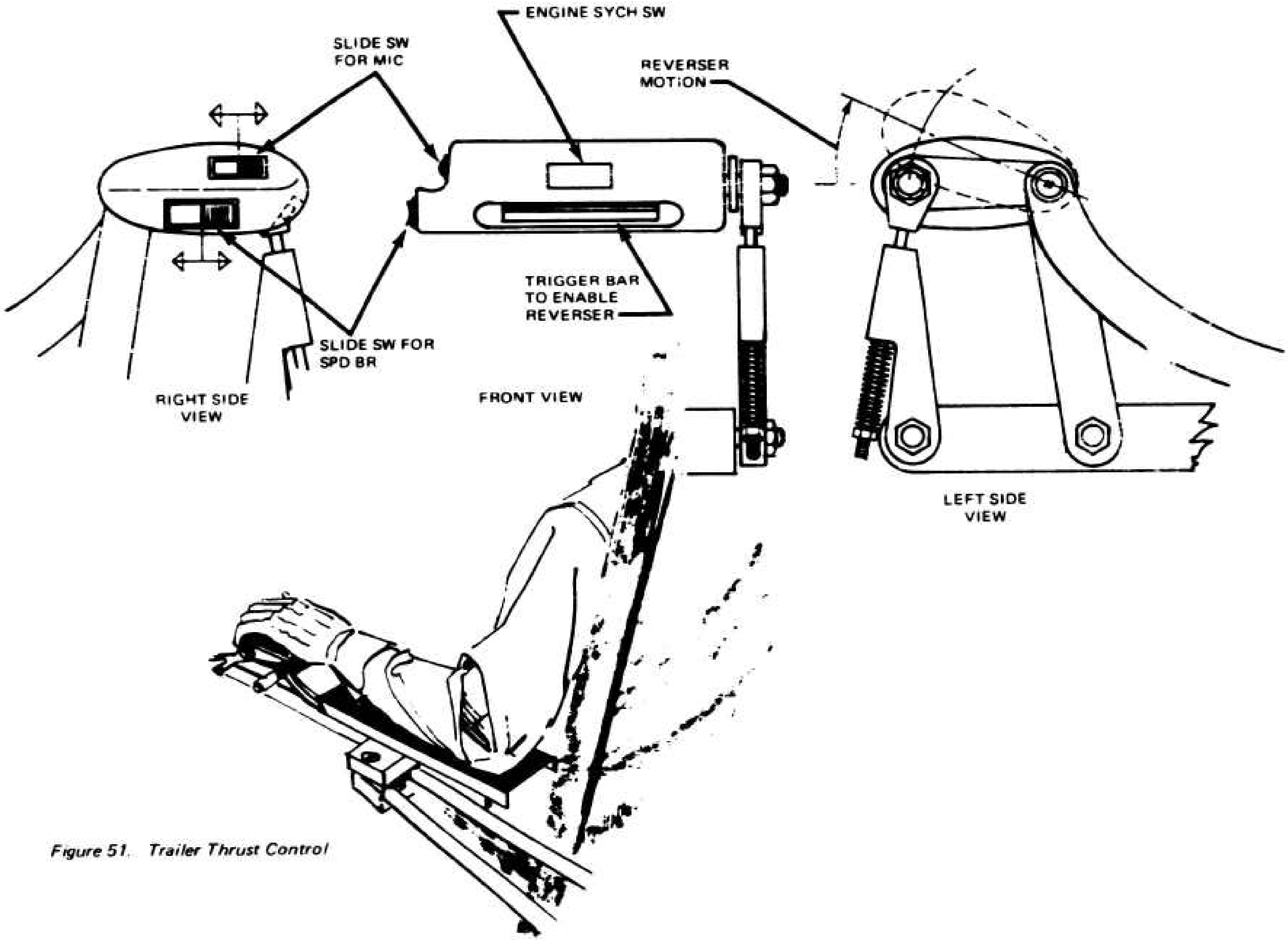


Figure 51. Trailer Thrust Control

The speed brake switch is on the lower part of the grip. It is spring-loaded against the aft (open) position and detented to hold the switch in the forward (closed) position.

If throttle control fails, engines may be managed in two ways: first, selection of command airspeed through autopilot/autothrottle system; and second, direct input via the computer of the thrust setting desired. The data may be entered either by voice or the integrated keyboard.

(d) Designation Controller

This control is required for cursor and sensor positioning during navigation updates, air-to-air tracking for IFF interrogation, and precision weapon delivery. In addition, the control may be used as a backup for the primary flight controller. Functional requirements for the designation or tracking control are to provide:

- o Cursor displacement in range, azimuth, and elevation
- o Target "lock-on" or "reject"
- o Switching functions for:
  1) ENABLE
  2) Freeze/Erase
  3) Navigation Update
  4) MMR Antenna Elevation

The rate of cursor movement is a function of displacement angle. The handle returns to the neutral position (upright) when released.

The designation controller shown in Figure 52 stows flush with the table when not in use. When the UNLOCK button is pressed, the control springs to the vertical position and may be operated with either hand. Cursor movement on a display (HSD, VSD, or MPD) is related directly to "North-Up", or "Heading-UP"--either option is available on the Auxiliary Radar/Map Control. Switch functions on the control are explained as follows:

- o ENABLE--Switch must be activated before any cursor positional functions are permitted

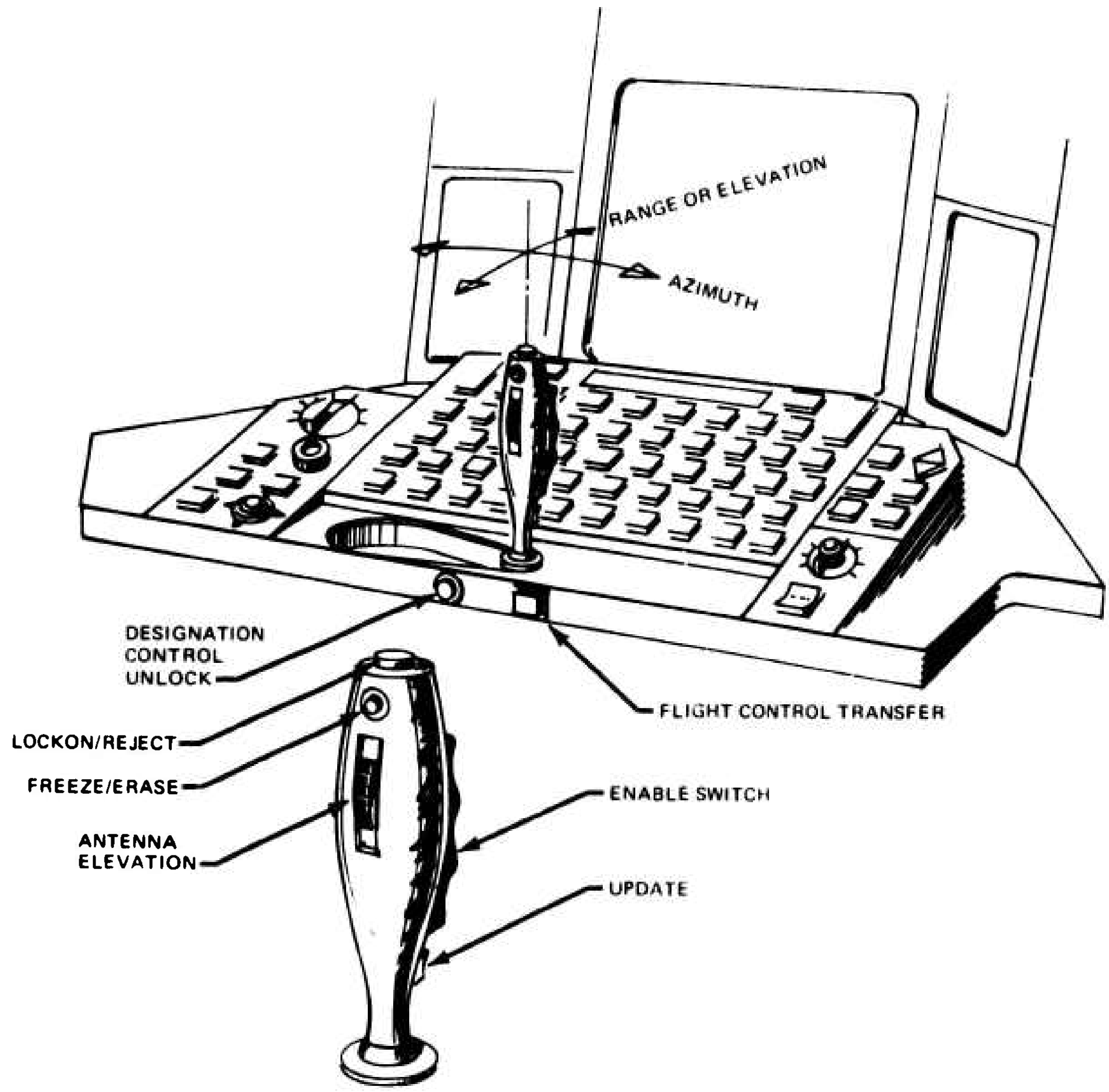


Figure 52. Designation Control (Stow Type)

- LOCKON/REJECT--Pushbutton switch with "first" and "second" detents for cursor lock-on or rejection of any target

- ANTENNA ELEVATION--Used in air-to-air combat flight mode. Permits MMR antenna elevation control during "spotlight" mode

- FREEZE/ERASE--Permits detailed examination of MMR and E-O presentations

- NAVIGATION UPDATE--Position updates the navigation computer after tracking a checkpoint

- BSD TRANSFER--Transfers the classic BSD to the HSD

- FLIGHT CONTROL TRANSFER--Transfers primary flight controller functions to the designation control

If all avionic systems function properly during a mission, the cursor is automatically controlled with the central computer. Through central computer program instructions, the cursor is displaced in range, azimuth, and elevation (depending on display and sensor selection). If all goes well, the designation control may remain "stowed" for the entire mission. However, if certain mission critical systems degrade, provisions are available for manual assistance in target acquisition and other tracking tasks. The designation control provides the pilot with an additional capability to designate and track any air or ground target--moving or stationary. In the degraded mode analysis, the primary method of designating and tracking a target was awarded to a stick-type control. Voice control is considered as backup and becomes primary when primary flight controller functions are performed by the designation control.

(2) Secondary Controls in a Primary Area

Secondary controls in a primary vision area are those that are used to directly select the flight display modes and to control sensor or airplane operation.

In the ensuing discussions of these controls, tables are presented to define modes of operation that are compatible or incompatible with one another. These are

preliminary and may require further investigation. Depending on the criticality of the assumed incompatibility, the computer could be programmed to disengage all incompatible modes when a new mode is selected. Some incompatibilities are due to the viewer not being able to use the information, not of the system being incapable of producing it. In some respects, the control flexibility called out by this study is probably considerably more than would actually be needed. An example of this is the capability to preprogram any of the many multipurpose presentation formats onto any of the four main MPD positions.

(a) Flight Mode and Display/Sensor Selection

Selection of flight modes (air-to-air, cruise, air-to-ground, and takeoff/land) causes several preprogrammed interactions to occur. Other actions affected relate to aircraft performance, e.g., stability control through cg location, flight control sensitivities, and flight control harmonization.

Normally, the VSD will present a contact analog display when the air-to-air, cruise, takeoff and land flight modes are selected. The exception to this classic program occurs whenever the aircraft is within 1,000 feet of the terrain, or whatever altitude is dictated by operational doctrine. At that point, terrain following "shades of gray" replaces the contact analog display.

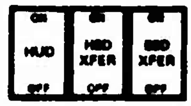
When air-to-ground is selected, terrain following is displayed. When a self-defense requirement exists while terrain following, selection of air-to-air will cause the appropriate fire control information to be superimposed over the terrain following display.

The contact analog and terrain following switches enable overriding of programmed flight mode display relationships. These switches provide a capability to perform degraded mode or mission unique manual operations.

The Display Sensor Select Panel has been modified as a direct result of the flexibility designed into the new Integrated Keyboard Control. The modifications discussed below provide a high degree of control over display and sensor options available to the pilot. Each control is described in detail.

(b) Displays

Selection of the HUD "ON" will cause the combining glass to erect, Figure 46. By means of liquid crystals, an opaque 1.5-inch circular area, as viewed by the pilot, appears on the glass for display of steerable LLLTV/FLIR video. The sensor presentation is parallax compensated, bore-sighted to line of sight, and focussed to infinity. The opaque area provides the pilot with video scene equivalent to a 9-inch CRT installed on the instrument panel. Placing the video on the combining glass provides two advantages over the instrument panel installation: 1) The TV/FLIR presentation is aligned with the real world in the forward search area. 2) The video is collimated at infinity, eliminating the delays incurred in eye accommodation as the pilot exchanges attention between the real world and TV/IR views.



Magnification of the Steerable LLLTV/FLIR can be changed from wide to narrow field of view with controls on the E-O Auxiliary Sensor Control panel. When the HUD "OFF" position is selected, the combining glass is removed from the pilot's line of vision to a stow position, Figure 46. Whether the HUD switch is ON or OFF does not affect the normal presentations on the VSD or HSD. Selecting the HSD TRANSFER "ON" will cause imagery on the HSD and VSD to shift upward. For example, the VSD presentation transfers to the HUD position (1), and HSD transfers to the VSD position (2). Had the HUD been in a stow position when this button was depressed, it would immediately erect and display the appropriate VSD information. The HSD position (3) becomes blank but available for BSD information if the BSD transfer switch is activated.

Selecting the BSD TRANSFER "ON" will transfer the BSD presentation, normally on a classic MPD, to the HSD (3). The imagery (RADAR) on the HSD will disappear; however, map data may still be presented simultaneously with BSD information by simply depressing the MAP "ON" button located on the Auxiliary Radar/Map Control Panel.

(c) VSD/HUD Sensor Select

The RADAR "ON" switch will allow radar targeting information (crosshair, target symbols, etc.) to be displayed on the VSD/HUD simultaneously with other imagery (TF/TA shades of gray, attitude, ITEMS flight director, fixed and steerable TV/FLIR). The switch "ON" and "OFF" does not affect information being presented on the HSD.

The LLLTV STEERABLE/FIXED sensor select is a three position pushbutton rocker switch with a center OFF position. Selecting the FIXED and/or STEERABLE position permits FIXED and/or STEERABLE TV video to be displayed as a composite video on the VSD. Fixed LLLTV video is the primary scene with STEERABLE LLLTV scene (centered on the crosshair line of sight) shown in a small circular "cut-out" area. Steerable TV video will be presented on the HUD when the HUD "ON" switch is activated.

Selection of the FLIR STEERABLE/FIXED sensors for display on the VSD/HUD is similar to that just explained for the LLLTV. Because it is possible to interlace video from separate sensors (sometimes called "level splicing"), both LLLTV and FLIR sensors may be activated simultaneously and displayed on the appropriate displays.

(d) Supplemental VSD/HSD Mode Selection

The Supplemental MMR Mode Selector is used to select the following submodes as cued by the flight mode selected:

<u>Air-to-Air Mode</u>

- o AA-SEARCH/TRACK--Doppler processing is used to provide long-range detection of airborne targets during spherical search/track

- o DOGFIGHT--Permits a narrow azimuth sector to be volumetrically searched. Target lock-on occurs automatically when the pilot points the aircraft in the near vicinity of the target

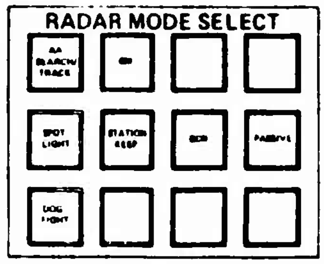
- o STATIONKEEPING--Provides stationkeeping on all aircraft located within a 2-nmi radius

- o BEACON (BCN)--Interrogates the airborne or ground radar transponder. The coded response appears on the HSD at the transponder location in range and azimuth and on the VSD in azimuth and elevation

- o PASSIVE--Places the MMR in a receive only mode for all modes except TF/TA

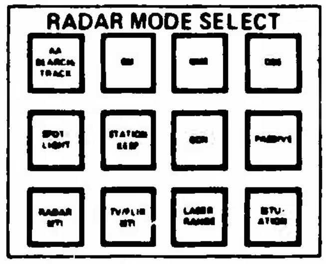
- o GROUND MAP (GM)--Provides conventional ground mapping data to the HSD

o SPOTLIGHT--(Degraded Mode) Provides manual search pattern capability with the MMR antenna programmed to a point in space. Numerical "bar scan" selection is provided in the keyboard.



AIR TO AIR

Air-to-Ground Mode



AIR TO GRND

o AA-SEARCH/TRACK--(See Air-to-Air Mode above).

o MOVING TARGET INDICATOR (MTI) RADAR--Detects targets moving with a ground velocity of 5 knots or more

o MTI - LLLTV/FLIR--Detects targets with E-O sensors same as radar above.

o GM--Provides conventional ground mapping data to the HSD

o GROUND MAP SQUINT (GMS)--Aligns the antenna beam to produce a high resolution "passing scene" map at 45 degrees left or right of ground track. Swath width selection is made with the keyboard control. Range selection is provided on the Radar/Map/Display Auxiliary Control

o SITUATION--Processes radar data to indicate only ground features protruding above the flight path clearance plane. Presented on the HSD

o SPOTLIGHT--Provides high resolution radar imagery of an area (1 x 1, 2 x 2, or 4 x 4 nmi) about the crosshair

o AIR-TO-GROUND LASER RANGING (AGRLR)--A pencil beam (LASER) is directed at the designated target to measure range

o DOPPLER BEAM SHARPENER (DBS)--Provides ground mapping resolution improvement when the MMR antenna is more than ± 5 degrees off ground track

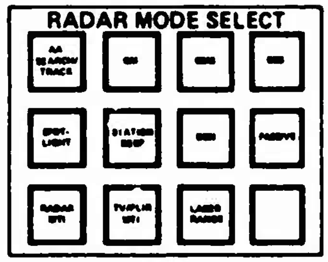
o PASSIVE--(See Air-to-Air Mode)

o STATIONKEEPING--(See Air-to-Air Mode)

o BEACON--(See Air-to-Air Mode)

Cruise

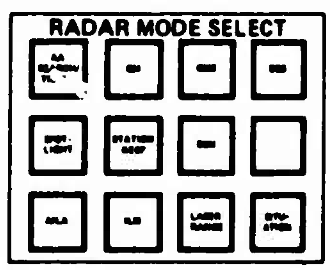
- o AA-SEARCH TRACK--(See Air-to-Air Mode)
- o STATIONKEEPING--(See Air-to-Air Mode)
- o GM--(See Air-to-Ground Mode)
- o GMS--(See Air-to-Ground Mode)
- o SPOTLIGHT--(See Air-to-Ground Mode)
- o BCN--(See Air-to-Air Mode)
- o DBS--(See Air-to-Ground Mode)
- o PASSIVE--(See Air-to-Air Mode)
- o LASER RANGING--(See Air-to-Ground Mode)
- o MTI - RADAR--_See Air-to-Ground Mode)
- o MTI - LLLTV/FLIR--(See Air-to-Ground Mode)



CRUISE

Takeoff/Land Mode

- o INDEPENDENT LANDING MONITOR (ILM)--Provides pitch and lateral steering to a point on the runway. In this mode, synchronized beacons are placed at specified points along the runway. Steering directions are based on position in space as measured with the MMR antenna in the "passive" mode, and calculated with the CCC.
- o STATIONKEEPING--(See Air-to-Air Mode)
- o SITUATION--(See Air-to-Ground Mode)
- o GM--(See Air-to-Ground Mode)
- o GMS--(See Air-to-Ground Mode)
- o SPOTLIGHT--(See Air-to-Ground Mode)
- o BCN--(See Air-to-Air Mode)



TO/LND

- o DBS--(See Air-to-Ground Mode)
- o AA-SEARCH/TRACK--(See Air-to-Air Mode)
- o LASER RANGING--(See Air-to-Ground Mode)
- o AILA--(Provides pitch and lateral steering through MMR tracking functions)

(3) Map/Radar/TV Auxiliary Panel

This control panel allows the pilot to select:

- o RADAR GAIN--Permits the pilot to adjust MMR receiver gain to the desired level
- o RADAR/MAP RANGE SELECT--Selects map and radar ranges in continuously variable steps from 1 to 40 nmi and incremental steps from 40 to 320 nmi
- o MAP SLEW--The map may be slewed from present position by depressing the button in the center and pushing the control in the direction desired. Used mainly for "look ahead." When released, the map returns to the computed present position.
- o MOVING MAP--Pushbutton control "ON" or "OFF" for presenting moving map data on the HSD display. May be activated any time regardless of HSD sensor selection (MMR or LLLTV/FLIR). Map scale is controlled with radar/map range select knob.
- o N-UP/H-UP--Provides north-up or heading-up display orientation for HSD
- o PPI/OCS--Permits pilot to select HSD PPI or OFF-CENTER SECTOR (OCS) during search or track operation, respectively
- o OFFSET--Selects OFFSET "ON" or "OFF" during offset bombing for "no show" targets. Also, used during AILA to track prominent "OFFSET" target during landing approach.

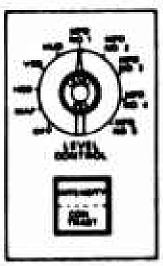
(e) Electro-Optical Auxiliary Control

The electro-optical (E-O) auxiliary control panel permits the pilot to select:

- INDIVIDUAL SLAVING--Permits the pilot to slave LLLTV/FLIR/LASER line of sight independent of the radar.
- BORESIGHT SLAVING--Slaves the E-O sensors sighting angle to the crosshair
- STOW--Stows the E-O sensors to "0" azimuth and elevation angles
- N-FOV-W--Selects a narrow or wide field of view for the LLLTV/FLIR sensors
- CONTRAST LOCKON--Permits the pilot to perform target lockon after designation with the cursor control. Lockon is based on target contrast levels.
- FAC TV FLTR--Pushbutton to insert or remove LASER illuminator filter during FAC target designation with LASER

(f) Display Level Control

The Display Level Control lets the pilot adjust the intensity or contrast of all displays through the following controls:



- DISPLAY SELECTOR--A detented rotary knob for selecting the HSD, VSD, HUD, and each of the five MPD's.
- LEVEL ADJUSTOR--A depress-to-turn knob provided for adjusting display intensity or contrast, depending on which is selected.

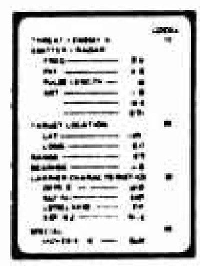
- o INTENSITY/CONTRAST--Lighted push-button selects either intensity or contrast as an operating mode for the level adjuster.

This control panel is conveniently located on the lap console in the brolly and wraparound cockpits. It is to the left of the left knee cutout in the centerstick cockpit.

(4) Battle Situation Control/Display

By using the integrated keyboard and CM panel, the pilot can selectively rather than collectively program and reprogram most penetration aid functions. Because time is limited, pilot actions are usually confined to veto and degraded mode operations.

In dense threat environments, it is possible to reduce BSD clutter manually. The control display and battle situation keys on the integrated keyboard, Figure 53, are used. The pilot can add or delete air and ground threats, priority, and launch envelope information. Excepted are terminal threats that cannot be deleted manually. Any one of the five MPD's or the HSD may be selected. The HSD is needed when it is necessary to work with numerous threats.



The pilot can manually request detailed threat characteristics, change threat identifiers, locations, and priorities. The BSD transfer switch is pressed to do this. This moves the BSD from an MPD to the HSD, allows threats to be addressed with the designation controller, and allows use of the vacated MPD for threat data detail recall.

The penetration aids key on the integrated keyboard is pressed to read out threat data details and make manual changes. The resulting keyboard is as on Figure 54. The threat is addressed on the HSD by the designation controller by placing the cursor over the threat of interest and pushing the lock-on button. Pressing the identity key will then provide MPD recall of complete computer stored threat data details. Direction finding steers will resolve nondeflection threat strobes in either active or passive radar modes.

Threats of opportunity are stored with the designation controller and the modify and location keys. When the pilot is satisfied that the cursor is properly over the threat, the lock-on button and the enter key are depressed.

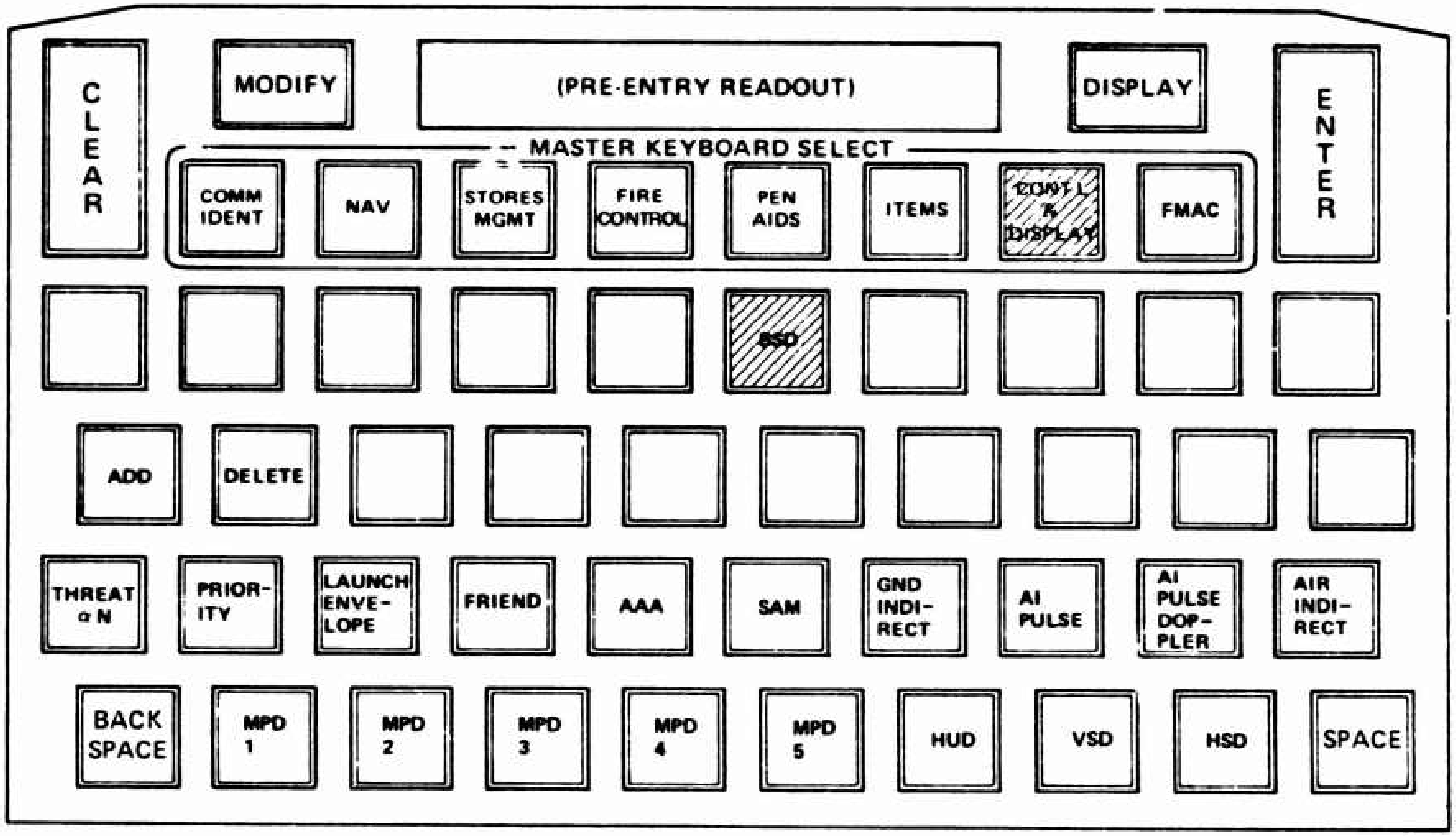


Figure 53. Control/Display Battle Situation Display Keyboard

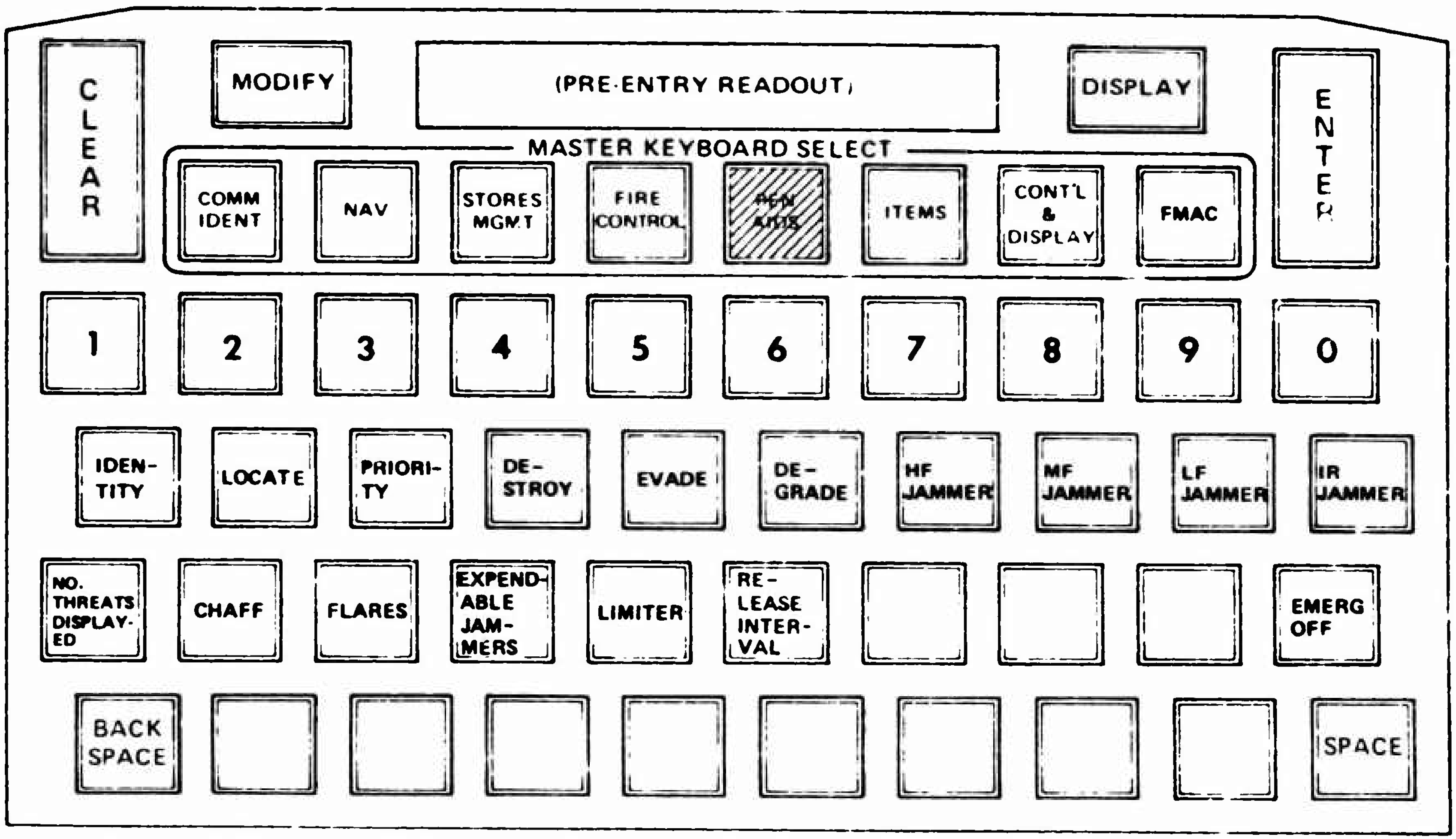


Figure 54. Penetration Aids Keyboard

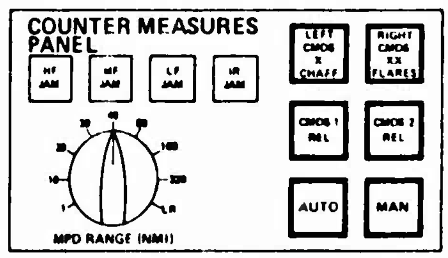
Priority and modify keys are used to change threat priority manually. The threat with a priority to be changed is addressed with the designation contro-ler. Then the new priority and a code for color is typed and entered.

Because judgment decisions are expected, manual selection of the offensive-defensive action options is allowed. Such actions are taken against the number 1 priority threat unless a threat is specifically designated with the designation controller. Then the designation controller provides a means to quickly override previously assigned priorities.

When the evade key is pressed, steering signals as previously discussed are shown on the VSD.

For degradation, quantities of chaff, flares, and other expendables to be released and release rates can be set up with the integrated keyboard. MPD readout of remaining expendables and other pertinent details are also provided.

Countermeasures can be selected and controlled by the CM panel. To enter the manual countermeasure mode, depress the "MANUAL" button on the CM panel. Depressing the appropriate countermeasures dispensing system (CMDS) button enables selection of a specific type or kind of expendable. Key words showing the type of expendable in position to release are shown on the CMDS release keys. Release is accomplished by depressing the associated CMDS "REL" button.



The range switch on the CM panel is used only when the BSD is located on an MPD. The long range (LR) position is to monitor all high altitude and low altitude activity. When the BSD is transferred to the HSD, the HSD range switch is used.

The integrated keyboard contains a "limiter" key to limit the number of threats allowed on the BSD.

If the "destroy" key is pressed,the battle situation and VSD presentations are the same as in the normal combat flight mode. Then the weapon can be

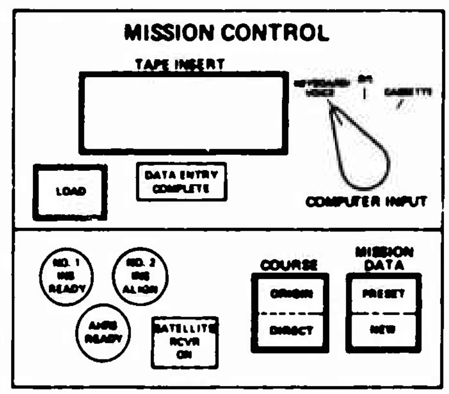
programmed and released either manually or automatically with the SMS.

(3) Secondary Controls

(a) Mission Control Panel

The mission control panel permits automatic and manual loadings into the central computer. The preprogrammed mission tape is placed into the "TAPE INSERT" cassette receptacle which may be used for readout or programming.

Operations that can be performed using this panel are described below:



- o AHRS STATUS--Displays alignment or operational status of the Auxiliary Attitude and Heading Reference System.

- o #1 and #2 INS STATUS--Displays alignment or operational status

- o Indication of the satellite tracking status

- o Computer Input

  - CASSETTE--Used when mission data tapes are loaded into the central computer

  - D/L--Used when mission data are loaded into the computer via data link

  - KEYBOARD/VOICE--This is the normal position for this switch. It allows use of the keyboard or voice for data inputs to the CCC depending on voice entry switch position on the throttle

- o LOAD--Permits loading the computer once the method has been selected

- o TAPE INSERT--Entry for loading cassette data into the central computer

- o DATA ENTRY--Provides data loading status

- o COURSE

  - DIRECT--Instructs the navigation computer to compute a course via the shortest route

  - INDIRECT--Instructs the navigation computer to compute a course for return to the preplanned flight route

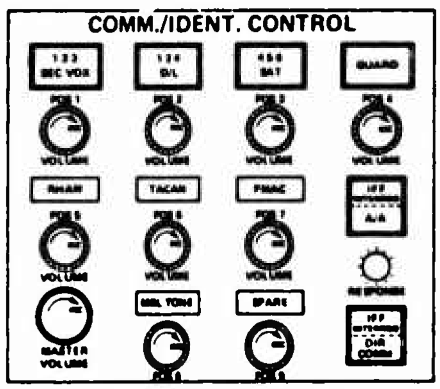
- o MISSION DATA

  - PRESET--The normal position for this switch. The flight follows the preplanned route

  - NEW--Used in conjunction with the Computer Input switch and the Integrated Keyboard to enter new destinations, targets, waypoints, checkpoints, etc.

(b) Comm/Ident Panel

The C&I control panel is the focal point for rapid selection of nearly all air-to-ground and air-to-air communications once the mode options have been selected with the Integrated Keyboard Control (IKC). IFF mode and code options are presented on an MPD. All communication modes, once selected on the IKC, are presented on a classic MPD display.

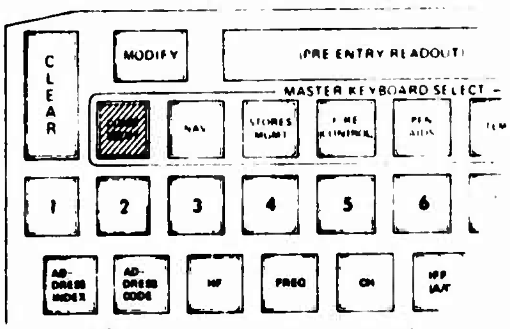


The panel, as shown, indicates at position one, destination 123. The SEC indicates the spread spectrum channel is programmed for secure voice. The multilegend pushbuttons illuminate at a low light level when programmed for receive only and brightens when depressed for transmit and receive. Up to to four positions may be activated for selective transmission, including guard. For positions one, two and three, the pilot must activate a transmit switch, located on the throttle control, before voice transmissions are actually

radiated from the aircraft. Data link tie-in is completed by simply activating the transmit pushbutton control. In position four, the pilot may transmit on GUARD without activating the microphone on the throttle control.

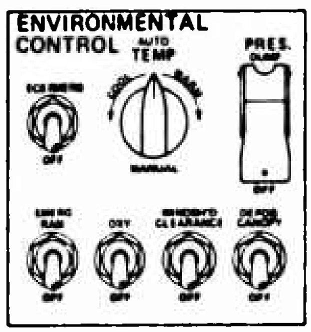
A second means of air-to-air IFF interrogation is needed for the degraded mode. The comm/ident panel has pushbutton controls for activating or inhibiting the conventional IFF (integrated with the phased- or conformal-array antenna) as well as the directional IFF (contained in the spread-spectrum communication link). A discrete light (labeled "RESPONSE") illuminates if the proper response is received by either interrogation method.

The identification keyboard is chosen by pressing the C&I key on the master keyboard select. This illuminates the identification options of the keyboard. Most options are self-explanatory for setting up all modes for air-to-ground and air-to-air. Both identification systems with respective modes and codes appear on the COMM. MPD classic display. In addition, the Directional Comm. and MMR IFF interrogate pushbuttons on the intercom panel light dimly, indicating systems programmed and ready for use. When either IFF interrogate button is pressed manually, it will light up brightly to indicate interrogation is being performed on the target designated by the tracking control cursor. A "RESPONSE" light on the ICS panel indicates receipt of a proper IFF response, in addition to the audio tune.



(c) Environmental Control Panel

The ECS panel controls cabin pressurization, temperature, humdity, and through rain removal and defogging, external vision. In addition, controls are available to provide the environmental conditions necessary to survive in emergency situations.



- o TEMPERATURE--Temperature is controlled automatically; however, the controller may be operated manually to provide comfort. Relative humidity is maintained throughout the temperature spectrum of control.

- o PRESSURIZATION/DUMP--Selecting the dump position turns the pressurization system off and opens gate valves to reduce cockpit pressure to ambient.

- o EMERGENCY RAM--Selection of emergency ram air when in the pressurization DUMP position provides a fast means for purging the cockpit of aerosols. Ram air is selected automatically when normal pressurization fails. The emergency ram air switch provides a redundant means for obtaining pressure when the system fails.

- o ECS EMERGENCY--When placed in the ECS EMERG position, this switch turns off the normal pressurization system and, with automatic or manual selection of emergency ram, provides cockpit pressurization.

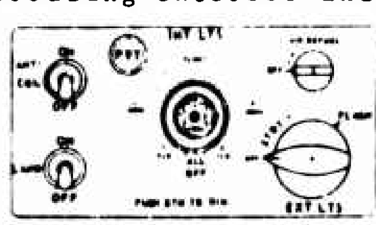
- o WINDSHIELD CLEARANCE--Actuation of this switch provides rain removal. Anti-ice heat to the windshield is provided full time by embedded heating elements.

- o CANOPY DEFOG--When activated, heated air is circulated between the canopy glass layers to eliminate or preclude fogging of the interior transparent material.

- o OXYGEN--If pressurization or ambient air is absent, emergency oxygen can be provided by activating this switch.

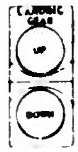
(d) Lighting Control Panel

The panel controlling exterior and interior lighting is located to the right of the major displays. The exterior controls are quite conventional and their operation is self-evident. The interior light control is new and uses an unusual method to control cockpit lighting and display brightness from a single point. To operate the internal intensity control, the pilot visualizes it as being located directly in front of him; that is, between him and the lap console or instrument panel. Each line radiating out from the center of



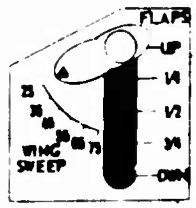
the control represents a specific control panel or display area relative to the central position. For example, the control is pushed directly up to change brightness on the flight mode select panel. Similarly, to decrease the intensity of the stores select panel, the center button is pushed in and the control is pushed to the left at about the 90° position. Beyond this 90° position, the panels on the left console are controlled. The right or left floods are controlled by moving the control to the R or L FLD position.

(e) Landing Gear Control



Two simple pushbuttons are used to control the landing gear position. Indication is provided on MPD #5.

(f) Flaps and Wing Sweep Selector



A single handle is used to control both wing sweep and flaps. The two functions are interlocked so that only one can be selected at a time. Selection of any wing sweep other than the minimum 25° position requires the flaps to be in the UP position. Likewise, selection of any flap down position requires the wing sweep to be in the 25° position. Wing sweep is obtained by handle rotation while flap position is changed by handle translation. Position feedback is provided to the wing sweep selector during normal automatic wing sweep operations. Pushing the wing sweep selector in will permit override of the automatic wing sweep mode.

The arrestment switch located on the panel just ahead of the flight controller, was added so that equipment necessary to stop the aircraft at the end of the runway could be extended or retracted.

The emergency beacon is activated upon ejection. The emergency beacon disable switch permits the pilot to turn the emergency beacon off to prevent detection by enemy forces. This button switch is located on the right side of the front panel.

An abort switch is located on the panel just to the outboard side of the forwardmost

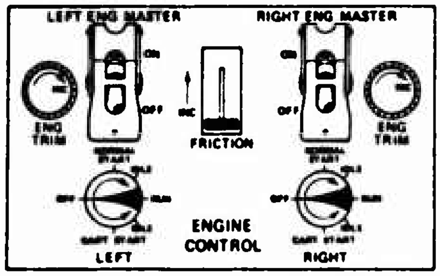
position of the throttle. Activation of this will cause:

- o Thrust reversal
- o Spoiler extension
- o Wheel brake application
- o Arresting equipment extension

(4) Tertiary Controls

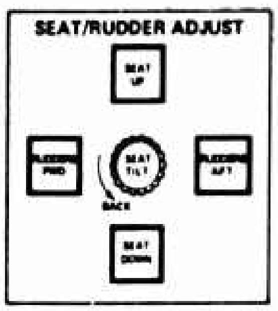
These controls are located on the side panels and are seldom used during flight.

(a) Engine Control Panel



Controls on the Engine Control Panel are used to start, trim, and shut down the engines. In starting the engines, the two rotary switches are placed in the OFF position and the guarded switches are turned ON. Then the rotary switches are moved through the NORMAL START position to IDLE and the engines start automatically. When the start is assured, the switch is placed into the RUN position.

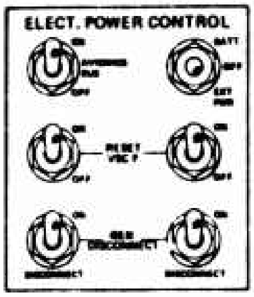
When the APU cannot be used for a start, the rotary switch for one engine is moved through the CARTRIDGE START position to IDLE and the engine starts automatically. When the start is complete, the switch is placed in the RUN position. When placed in the RUN position, the FRICTION lever controls the amount of force required to move the throttle.



Seat and rudder adjust and arrestment controls on this panel are self-evident.

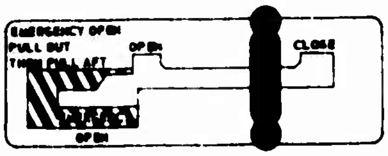
(b) Electrical Control Panel

Switches on the Electrical Control Panel are used to select the electrical power source used during startup and to permit manual disconnect of the alternator from the engine (subsequent to automatic disconnect if failure occurs). In addition, the variable-speed, constant-frequency converter is controlled and can be reset.



(c) Canopy Lock/Release

This mechanism controls the normal and emergency canopy operations.

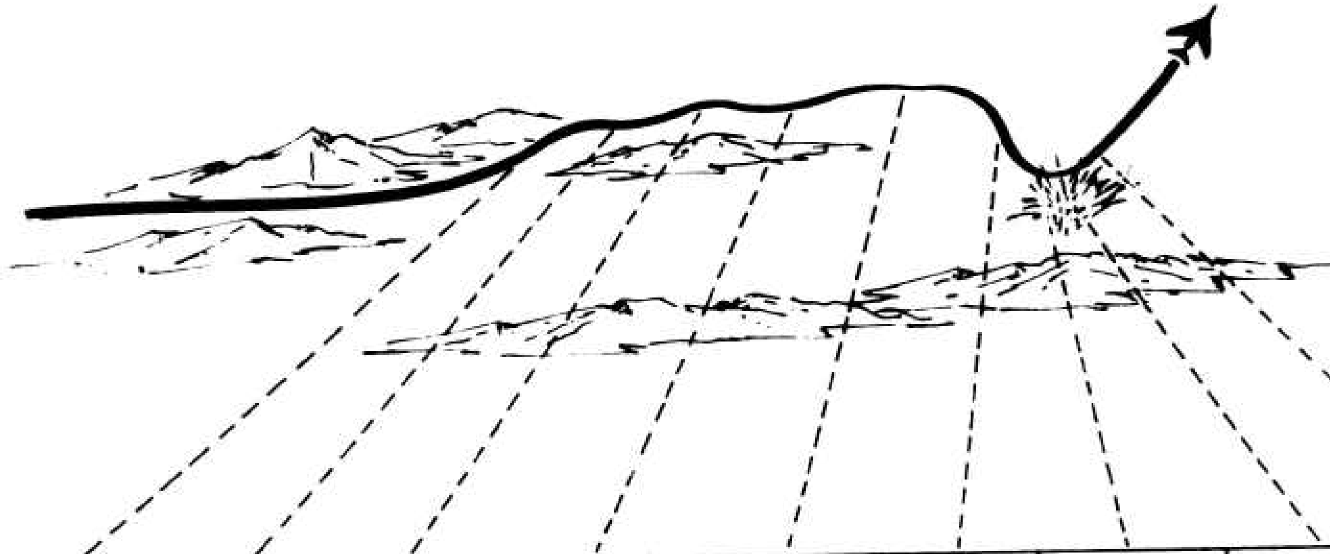


7. SUMMATION OF RESULTS AND DISCUSSIONS

The primary purpose of the tactical fighter is to deliver weapons on targets. The task must be accomplished with the fighter surviving any deterrents the enemy may have to protect the targets. This dictates a fighter with capability for a single pass kill and agility to maneuver and vary velocity to evade threats throughout the task. It must lock-on the target, quickly attain the weapon release vector, pull a large g load, and rapidly accelerate for escape after weapon release. The fighter must be able to accomplish the attack task with a variety of methods and weapons to increase target vulnerability. It must have flexibility for successfully meeting the many threat, target, terrain and weather environments. Weapon delivery options using a full spectrum of delivery tactics are required. Since the task is especially time constrained, the fighter must be able to do it quickly; e.g., the entire task may last as little as 20 seconds in a dense threat environment. Precision weapon delivery on the correct target is required since some targets must be struck with a CEP less than 4 feet. The tactical fighter needs a self-defense capability--carrying weapons for neutralizing both air-to-air and ground-to-air threats.

These critical requirements directly impact and drive tactical fighter design. All subsystems must be optimized and integrated for this end to achieve a superior attack task capability. Accordingly, the IIPACS concept is being developed for the successful execution of the attack task. Of necessity, it reflects innovative design solutions to achieve a superior, viable improvement over today's tactical weapon systems. Considerable equipment complexity, compared to today's systems, is incorporated into IIPACS to ensure required capability. This complexity is not considered a disadvantage, because high reliability and self-test features are an integral part of the basic concept. Proper use and allocation of complexity enhances system capability with cost benefits when the primary weapon system figure-of-merit is considered; i.e., pounds payload per target destroyed.

The attack task is functionally described in Figure 55. It starts with correct target acquisition and culminates in a successful escape from the target after a precise weapon release. Existing problems associated with



FUNCTIONS	SEARCH	IDENTIFY	LOCK-ON	CLASSIFY AND SELECT WEAPONS	CONVERT	ENTER SLOT, REFINE AIM, & VERIFY TARGET	RELEASE	WEAPON GUIDANCE	ESCAPE AND DAMAGE ASSESSMENT
MAJOR PROBLEMS	• GEO-ORIENT • SENSOR DISPLAY • SEARCH AIDS • TRAINING • RECON/BRIEF	• BRIEFING AIDS • COMPUTER REF • SENSOR/ DISPLAY • TRAINING • DISPLAY AIDS	• SENSORS • DESIGNATION CONTROL • COMPUTER AID	• WEAPON/ TARGET MATCHING • WEAPONS MANAGEMENT	• TA RANGE • MANEUVER-ABILITY • WEAPON RQMTS • SURVIVAL • TRAINING	• STEERING • SURVIVAL • TRAINING • COMPUTER AID • DISPLAY	• WEAPON INSTALL/ SEPARATION • A/C STABILITY • PATTERNING • CCIP COMPUTATION	• AUTO TRACK • SENSOR/ DISPLAY • MANEUVERS • REMOTE CONTROL	• SURVIVAL • SENSOR RECORD AND RECALL • DELIVERY PARAMETERS RECORD & RECALL

Figure 55. Tactical Attack Mission

the accomplishment of each task element are summarized in the same figure. They are today's problems which IIPACS attempts to solve. While sufficient data are not available to demonstrate IIPACS does solve these problems; it does appear that the concept is pointed in the right direction. As IIPACS is refined and tested under both simulated and actual flight conditions, these problems need to remain in the forefront to ensure their resolution.

The major IIPACS subsystems involved in the attack task are presented in Figures 55 and 56, along with a summary of information flow within this interface complex. This complex (called the attack subsystem to identify its function) recognizes the impact of combat stresses and workload variations on pilot performance. Full advantage is taken of the highly reliable, large capacity computer systems forecast for the 1980 time period. Two redundant, federated computer complexes are included in IIPACS to form a primary control center to relieve the pilot of all attack workloads except target acquisition/verification. This control center interacts with the pilot in real-time and is managed by the pilot usually with voice inputs during this busy phase of the mission. The pilot is expected to augment the computer in the area of threat management by inserting current threat configuration information obtained visually or via sensor interpretation. The computer, in turn, will augment the pilot in target search identification and classification by providing predicted target locations, descriptions, enhancement cues, and processed video. In specific instances, the pilot must select and designate the target.

To assist the pilot in optimizing the survival/precision weapon delivery trade, the computer predicts weapon impact point and CEP spread and best delivery path for threat evasion. Airplane steering precision, response, and stability are enhanced for both autopilot and pilot control. Control stick steering modes oriented toward flight path control or attitude control working in conjunction with special force generators in the airplane provide improved agility and the capture of the weapon release vector. The pilot may select airplane stability characteristics to optimize those needed for air-to-ground work and those for air-to-air self-defense work. Research is required to optimally define design requirements for the required novel airplane control characteristics.

To enhance pilot protection, the windshield provides protection from 7.62mm shells and crew station titanium protects against 23mm shells. It is desirable that the windshield handle 23mm shells; however, research is required to determine design feasibility without degrading pilot

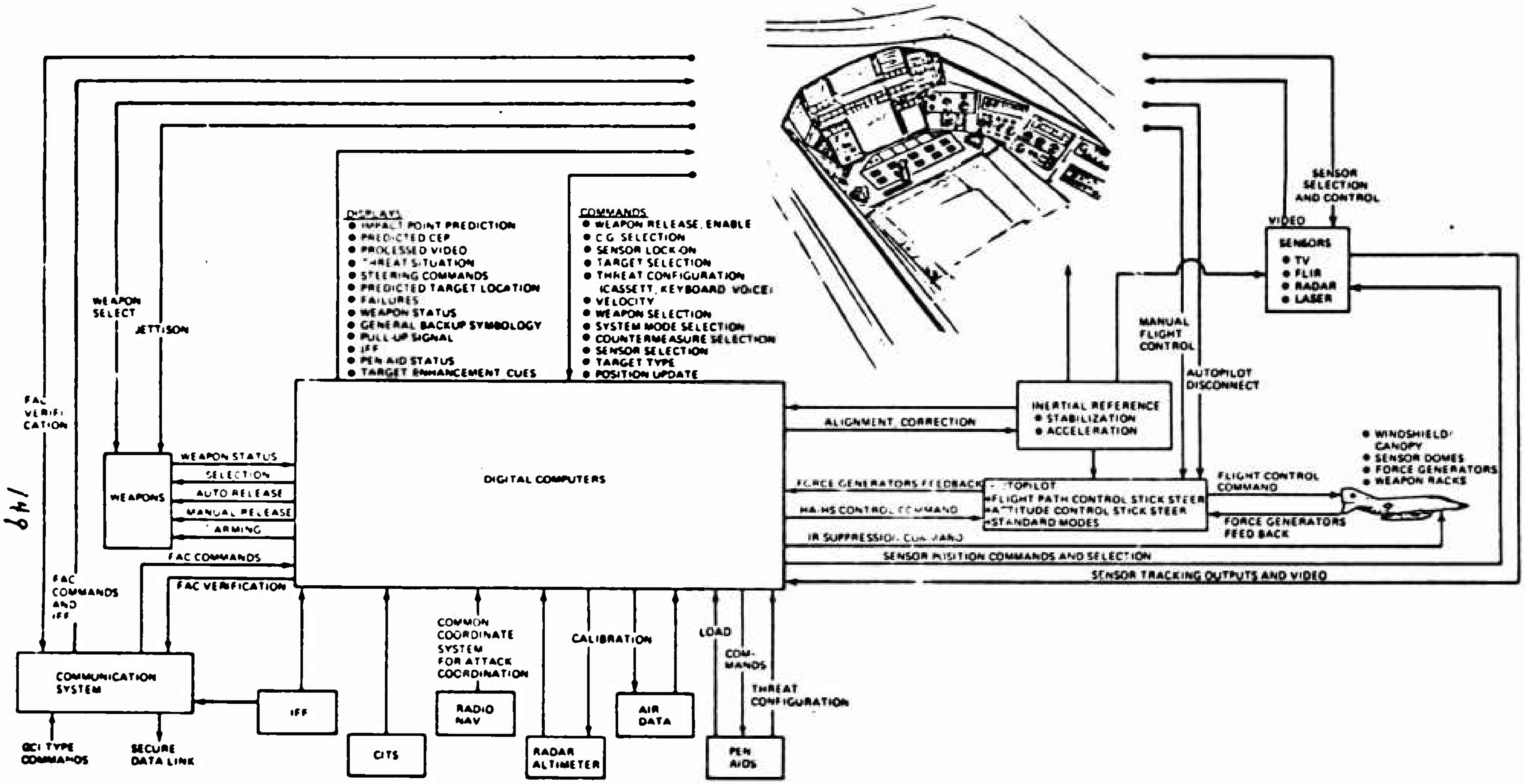


Figure 56. Attack Interface Diagram

visual target acquisition capability. It may be necessary to add a steerable telescope to IIPACS for target identification to permit proper windshield armor installation or install the pilot in a non-standard manner to reduce windshield vulnerability area.

It is apparent that the key to the advanced attack subsystem concept summarized here is the joint, interacting control centers incorporated into IIPACS--the pilot and the computer. Development work is required to detail these control centers and identify exactly:

- How they must interact
- Their command task allocation
- Their cooperative aiding
- Intercommunication links and techniques
- Overrides and software

Technology is available. It remains to take full advantage of this capability to optimize the pilot-computer integration required for successful cost/effective attack task performance.

Details concerning the individual subsystems identified for the attack task are presented in previous sections of this book.

SECTION IV

CONCLUSIONS AND OBSERVATIONS

1. CONCLUSIONS

The three advanced tactical fighter cockpit configurations resulting from the IIPACS-1 study (Volumes 1 and 2) are feasible for development circa 1980. Since current specifications and standards were not a conceptual constraint, these cockpit configurations are substantially different from current aircraft. Development progressed from a systems-type analysis to mockup configurations.

The wraparound cockpit of an updated IIPACS-1 tactical fighter weapon system provided the baseline configuration for the degraded mode analysis. The study results provided control and display modifications and additions designed to permit a high degree of survivability and mission completion after sustaining failures to an identifiable level.

Specific conclusions are:

- IIPACS concept, updated in response to advancing technology, offers a significant advance in tactical weapon system effectiveness.

  Through a dependent system of automation, a reduction of pilot workload will be realized.

- Time-sharing techniques and multipurpose controls and displays improve the integration of information and control functions is feasible.

- Avionics concepts will provide a high degree of flexibility, thereby simplifying growth and updating problems.

- Workload per unit of time during anomalies may well drop below that of normal operations. This is attributed to the fact that the pilot defers normal operations during contingency situation. This was borne out by the degraded mode workload evaluation and verified in film reviews of A6 emergency operations.

- The controls and displays developed as a result of the degraded mode analysis will permit contingency operations without an overburdening pilot workload.

- Weapon delivery accuracy requirements determine weapon system design criteria. Systems integration is vital to the realization of an effective weapon system. Airframe and weapon designs must be complimentary to the avionics/fire control systems.

- IIPACS-2 automation approaches those required for an unmanned system. For specific missions and certain weather conditions, a pilot is still required on-board for target acquisition and verification.

- The IIPACS has been defined sufficiently for full mission simulation.

- The IIPACS concept is flexible enough that it can apply to systems other than tactical fighters.

2. OBSERVATIONS

During this study, it became evident that certain problems relating to the weapon system should be pursued in future research and development programs. The following paragraphs briefly describe specific areas of concern.

a. Automatic Target Acquisition

Automatic target acquisition is a high priority problem area. A major breakthrough is required to advance the technology of manned vehicles. As such, sensor data correlation and image processing techniques present the greatest challenge.

b. Integrated Total Energy Management System (ITEMS)

A total energy management system permits integration of the elements of flight normally performed by an already overburdened pilot. The system will optimize aircraft performance while relieving the pilot from inconsistent and inefficient integrative and interpretive tasks.

As the term "total energy" implies, all energy exchange factors must be considered in determining an optimum flight path and its relationship to a selected point, fixed or in motion. The parameters and equations required to mechanize ITEMS need to be identified.

c. Spherical/Conformal Array Antenna System

Conformal array antennas, transmitters, receivers, and associated computer programming need to be investigated. The uses for such a combination of elements include emitter location in spherical coordinates, emitter classification, and spherical air-to-air search. This study should define the requirements for frequency and volumetric coverage, accuracy, power, etc. From these requirements, the hardware should be breadboarded to prove concept feasibility. One area that needs considerable study before desired results can be achieved is the computer sizing and programming.

d. Solid State Display Devices

Further work is needed to develop a solid state display technique which can satisfactorily replace the CRT by the 1980-85 time period. The use of time-sharing techniques presented in this study is indicative of the trend toward multifunction displays. Currently, light emitting diodes show great promise as a suitable display technique in the IIPACSS technology time period.

Experimentally, liquid crystals have been used in place of phosphors in a CRT. Ambient lighting enhances the brilliance of a liquid crystal cathode ray display as opposed to the washout of the phosphor CRT in such an environment. An additional benefit of research in the liquid crystal field might be control of canopy transmissivity as protection against strong ambient light conditions or visible energy from special weapons. Obliteration of the glass face of inoperative instruments in lieu of warning devices would be still another application of liquid crystals. Thin film EL offers yet another alternate for the aircraft cockpit application; however, its development may take longer than the two techniques previously mentioned.

e. Simulation

The concepts evolved in this study must be evaluated. A simulation program can determine the feasibility of the unique features of the control/display concepts developed in the study. In addition to comparing the IIPACS configurations, the following innovations may be assessed:

- Flyability of displays that are purely qualitative.
- In-flight authority over control sensitivity, harmonization, wing sweep, and cg.

- o Weapon management.
- o Voice command,
- o Degraded mode operation.

f. Multiplexing Standardization

Accelerated use of digital techniques introduces the problem of digital interface compatibility. The advantage offered by a common digital language and transmission may be intuitively accepted. All electrical/avionic equipment for this aircraft should be procured to a specification that includes standardization of the following interrelated elements:

- o Modulation technique.
- o Message structure.
- o Sample rate.
- o Interface signal definition and signal conditioning.
- o Interface system definition.
- o Bit/clock rate.
- o Transmission line characteristics.
- o Line drive and receiver elements.

g. Voice Commanded Equipment

Voice command of equipment provides an effective means for reducing foot/hand workload. An additional benefit to voice commanded equipment is the elimination of the visual or tactile task requirement prior to the foot/hand actuation. A working model of such a device has been developed. A production model and exploitation of the voice command device has as yet to be accomplished.

h. Collateral Missions

Almost all combat aircraft presently used are employed in missions for which they are not designed. To avoid the problems of "growth" so prevalent in present aircraft, the advanced tactical fighter calls for a design capable of coping with the diverse environs of geography and the many gradations of "cold," "limited," and "hot" wars. Trends of future mission requirements must be determined to facilitate design of this flexible weapon system. A

collateral mission study could provide the necessary information and indicate alternatives.

i. Adaptive Controls and Stability

Control sensitivity and harmonization is of paramount importance in aircraft design. In-flight authority over control sensitivities (gains) would permit the tailoring of flight controls to match the needs of each operational mode expected to be flown by the tactical fighter. Additional flexibility would be gained with control over cg and wing sweep.

j. Data Link

While the advantages of data link are well known, its usefulness depends on RF vulnerability. When not jammed or assuming that secure data link could become a reality, its advantage as a maintenance tool can be expanded to alleviate cockpit workload. By transmitting real time information to a remote monitor, system trends could be noted, anomalies could be anticipated. and the skilled individual could act for the pilot, especially during mission-critical emergencies.

k. Central Computer

The multiprocessor, multimemory computer must be simulated on an existing computer so that its performance and the performance of the computer solving the various types of data processing problems encountered in an avionics system can be studied. This will ensure that when the computer is actually constructed, it will fulfill all design requirements.

Partitioning of equipment in the avionics system must be analyzed to determine where commonality of processing is done for many different subfunctional elements as well as sensors. If this repetition of common processing occurs, the processing functions will be combined to conserve total computer requirements. This elimination of redundant processing is made possible through the concept of a centralized computing function.

Concepts such as the multifrequency, multiaperture antenna system and multispectral target detection and identification systems which are not part of the present F-15 Avionics System must be analyzed. These new concepts have the potential of adding significantly to the 1980-85 avionics system's performance. The requirements that these systems will place on the functionally centralized computer must be identified, and an estimate of their effectiveness must be made.

The Integrated Presentation System and the IMS System must be interfaced for the system of the 1980's.

Communications, navigation, and identification (CNI) system interface with the IMS requires additional investigation.

1. General

Additional analysis and supporting simulation test are needed to detail the computer-pilot interface for target acquisition and threat management during attack.

Special study is required to detail the display-flight control system-pilot interface to optimize evasive agility maneuvers, target capture and tracking, weapon release, and escape maneuvers during attack.

Research is necessary to optimize pilot protection during attack without compromising needed visual range for target acquisition and verification.

Test and analysis are required to determine the impact of electronic displays on crewstation lighting requirements.

In an environment where bugs, salt spray, dust, etc. are present, the transmissivity of the windows for the electro-optical sensors for the aircraft and the weapons may be compromised. A means for ensuring E-O sensor window transparency is considered an essential requirement.

The carriage of weapons with integral guidance sensors has been a perennial problem. A method for reducing airframe interference to an acceptable level while exacting a minimum penalty from either the weapon or the aircraft must be devised.

The concept of an integrated engine-generator system (IEGS) warrants investigation. The system uses a generator mounted on the engine shaft and is intended to be used as a motor for engine starting as well. Advantages are that it:

- Increases electrical power extraction
- Reduces pneumatic and hydraulic penalties
- Reduces takeoff gross weight
- Minimizes frontal area engine

- Reduces the size of the engine accessory gear box

This study defined the equipment necessary to perform the normal and contingency operations of a tactical mission. The pilot is considered an integral part of the weapon system. No attempt has been made to analyze the system's degradation as a result of the pilot's incapacitation to any level. A separate study is required to determine the impact the "subsystem man," when degraded, has on overall weapon system effectiveness.

APPENDIX I

FAILURE RANKING AND RELIABILITY ESTIMATE

1. FAILURE RANKING

In a contingency situation, a pilot must make a decision to continue or abort a mission based on the observed status of the aircraft and the availability of accep able alternates. A casualty may be either induced by battle damage or the result of a failure. Field experience provides an indication of those subsystems most prone to failure and is used in this study to assist in establishing a priority for subsystems and failure modes to be subjected to degraded mode analysis.

A summary of current-inventory fighter aircraft failures and failure distribution is presented in Figure I-1. These data represent a summary of AF 66-1 failure reporting for continental U. S. operation and exclude battle-induced failures. The figure is presented to accent the finding that the pilot of today's aircraft is not aware of a majority of the failures occurring to his aircraft.

Less than one-fourth the total listed aircraft failures are detected in-flight while it is assumed that nearly all failures do occur in, and as direct result of, flight stress. Conceding some failures to be maintenance-induced and that some reported failures are trivial, there is still clear indication that a requirement for better failure detection does exist. This study treats undetected failures in a qualitative manner by planned incorporation of a failure monitor and control system (FMACS), and by control-display integration to detect and minimize the effect of failure.

To define a point of study departure, the F-4C and the F-111A were evaluated as the guide for a functional and fault mode model. The F-111A functional capabilities were assessed to more closely approximate those defined by the IIPACS flight scenario. The F-111A data base is AF 66-1 CONUS field data reduced and summarized by the Boeing, Military Airplane Systems Division, Data Center. These data form a decision parameter in the man-machine trades, the FMACS implementation, the controls and displays selection, and the priority of Degraded Mode Analysis performance. Figure I-2 provides a ranking of F-111A failures and air aborts at the subsystem level. Figure I-3 provides a lower indenture ranking of subsystem failures. Figure I-4 provides failure and air abort rates per 1,000 flight hours at the two-digit Work Unit Code (WUC) level.

FIGURE I-1. FIGHTER FAILURE SUMMARY

	F-105D	F-104C	T-38A	F-5A	F-4C	F-111A
1. Total Failures per 1,000 Flight Hours	3,809	3,463	1,234	872	1,596	1,454
2. Percentage of Total Failures Discovered in Flight	12%	12%	10%	7%	22%	24%
3. Distribution of Total Failures						
a) Electronics	28%	22%	5%	14%	28%	30%
b) Instr. - Autopilot	6%	4%	5%	3%	6%	5%
c) Propulsion	12%	20%	51%	46%	10%	16%
d) Airframe - Utility	54%	54%	39%	37%	56%	49%
	(100%)	(100%)	(100%)	(100%)	(100%)	(100%)
4. Distribution of Failures Discovered in Flight						
a) Electronics	60%	47%	33%	34%	63%	66%
b) Instr. - Utility	18%	8%	10%	28%	5%	12%
c) Propulsion	6%	2%	33%	15%	5%	7%
d) Airframe - Utility	16%	43%	24%	23%	27%	15%
	(100%)	(100%)	(100%)	(100%)	(100%)	(100%)
5. Percent Flight Undetected Failures						
a) Electronics	74%	74%	34%	83%	51%	47%
b) Instr. - Utility	64%	76%	80%	35%	82%	42%
c) Propulsion	94%	99%	94%	98%	89%	90%
d) Airframe - Utility	96%	90%	94%	96%	89%	93%

FIGURE I-2. F-111A FAILURE AND AIR ABORT RANKING

WUC	SUBSYSTEM NOMENCLATURE	FAILURE RANKING TOTAL	FAILURE RANKING DISCOVERED IN FLIGHT	AIR ABORTS RANKING
11	AIRFRAME	1	-	11
23	TURBOJET POWER PLANT	2	3	1
73	INERTIAL BOMB-NAV	3	1	5
75	WEAPONS DELIVERY	4	18	12
14	FLIGHT CONTROL	5	8	4
13	LANDING GEAR	6	14	8
52	AUTOPILOT	7	5	2
45	HYDRAULIC & PNEUMATIC PWR.	8	16	7
76	ELECTRONIC COUNTERMEASURES	9	2	16
51	INSTRUMENTS	10	4	10
44	LIGHTING	11	13	17
41	AIR CONDITIONING & PRESS.	12	11	6
46	FUEL	13	10	3
16	ESCAPE CAPSULE	14	17	-
71	RADIO NAVIGATION	15	6	-
63	UHF COMMUNICATIONS	16	9	15
42	ELECTRICAL POWER	17	20	14
64	INTERPHONE	18	7	13
61	HF COMMUNICATIONS	19	12	-
74	SIGHTING & CONTROL	20	15	-
47	LIQUID OXYGEN	21	19	18
49	FIRE DETECT & EXTINGUISH	22	-	9
86-97	(MISCELLANEOUS)	23	21	-
69	COMMUNICATIONS EQUIPMENT GEN.	24	-	-

FIGURE I-3. F-111A FAILURE RANKING

SUBSYSTEM	FAILURES DETECTED IN FLIGHT	FAILURES
FUSELAGE	-	1
TERRAIN FOLLOWING RADAR (APQ110)	1	2
ENGINE AIR INLET SYSTEM	14	3
WEAPONS PYLON INSTALLATION	0	3
INERTIAL BOMB-NAV SYSTEM (ATQ20)	3	5
RADAR SET (APQ113)	2	6
WEAPONS RACK SYSTEM	32	7
FLIGHT CONTROL SLAT SYSTEM	21	8
WINGS	-	9
A/B FUEL SYSTEM	25	10
WHEELS & TIRES	57	11
ENGINE THROTTLE SYSTEM AIRFRAME	16	12
WEAPONS BAY SYSTEM	62	13
ENGINE INSTRUMENTATION SYSTEM	19	14
AUTO. FLIGHT CONTROL SYSTEM	9	15
FLAP SYSTEM	24	16
RADAR RECEIVING SET, ECM (APS-109)	4	17
UHF RECEIVER TRANSMITTER (ARC-109)	7	18
TACAN NAVIGATION SYSTEM	5	19
AIR CONDITIONING SYSTEM	15	20
ALTIMETER (APN-167)	6	21
UTILITY HYDRAULIC POWER SUPPLY	34	22
AUTOPILOT AIR DATA SYSTEM	8	23
PRIMARY HYDRAULIC POWER SUPPLY	46	24
EXTERIOR LIGHTING SYSTEM	41	25
CREW ESCAPE MODULE	40	26
BRAKE SYSTEM	66	27
AC POWER SUPPLY SYSTEM	39	28
FLAP/SLAT SYSTEM	28	29
FUEL INDICATING SYSTEM	11	30
MAIN FUEL SYSTEM	22	31
FLIGHT CONTROL ROLL CHANNEL	49	32
FLIGHT INSTRUMENTS GENERAL	12	33

FIGURE I-3 (Contd). F-111A FAILURE RANKING

SUBSYSTEM	FAILURES DETECTED IN FLIGHT	FAILURES
HF RADIO COMPONENTS (ARC-112)	17	34
INTERCOMM. SET	10	35
AUTOMATIC FLIGHT INSTRUMENTS	13	36
WEAPONS BAY GUN SYSTEM	-	37
FLIGHT CONTROLS, GENERAL	23	38
ECM RECEIVER SET (ALR-23)	18	39
ENGINE OIL SYSTEM TUBING	72	40
ENGINE FRONT & REAR FAN CASE SECTION	-	41
ENGINE OIL SYSTEM	33	42
LIQUID OXYGEN SYSTEM	31	43
FUEL SYSTEM INTEGRAL TANKS	70	44
ENGINE TURBINE SECTION	-	45
FLIGHT CONTROL PITCH CHANNEL	52	46
AIR-GROUND IFF (APX-64V)	20	47
INTERIOR LIGHTING SYSTEM	35	48
DC POWER SUPPLY	64	49
ESCAPE CAPSULE STABILIZATION GLOVE	4[illegible]	[illegible]
AUXILIARY INSTRUMENT SYSTEM	27	5[illegible]
WEAPONS CONTROL SYSTEM	55	52
AIR PRESSURIZATION SYSTEM	26	53
LIGHTING-WARNING & CAUTION COMPONENTS	42	54
ENGINE STARTING SYSTEM	78	55
SIGHTING & CONTROL SYSTEMS	29	56
LANDING GEAR DOORS	54	57
HF ANTENNA COUPLER GROUP	36	58
ESCAPE CAPSULE EMERGENCY SYSTEM	65	59
WING SWEEP SYSTEM	50	60
LANDING GEAR GENERAL	44	61
MAIN LANDING GEAR	67	62
ENGINE AFTERBURNER COMBUSTION SECTION	-	63
ECM INTERFERENCE BLANKER	30	64
SPEED BRAKE	47	65
NOSE GEAR	72	66

FIGURE I-3 (Contd). F-111A FAILURE RANKING

SUBSYSTEM	FAILURES DETECTED IN FLIGHT	FAILURES
ENGINE AFTERBURNER NOZZLE SECTION	73	67
NOSEWHEEL STEERING	56	68
FLIGHT CONTROL YAW CHANNEL	74	69
UHF/ADF (ARA-50)	48	70
ENGINE FUEL SUPPLY SYSTEM	69	71
ENGINE FAN-INLET SECTION	-	72
FIRE DETECTION SYSTEM	-	73
ENGINE IGNITION SYSTEM	68	74
PNEUMATIC-POWER SUPPLY	-	75
COUNTERMEASURES DISPENSING SET (ALE-28)	37	76
INSTRUMENT SYSTEM, INSTRUMENTS GENERAL	38	77
ENGINE MOUNT INSTALLATION	-	78
REFUEL/DEFUEL SYSTEM	51	79
ENGINE TURBINE EXHAUST SYSTEM	-	80
ENGINE COMBUSTION CHAMBER SECTION	-	81
ELECTRICAL POWER SUPPLY SYSTEM	61	82
ENGINE MAIN GEAR BOX	75	83
ENGINE (COMPLETE) (TE30)	76	84
ILAS (ARN-58A)	43	85
ARRESTING HOOK SYSTEM	53	88
PITOT-STATIC SYSTEM	53	88
SURFACE ICE CONTROL & EMERGENCY RAM AIR	77	89
FIRE EXTINGUISHING SYSTEM	-	90
ENGINE ANTI-ICING AIR SYSTEM	-	91
ENGINE COMPRESSOR PRESSURE RATIO SYS.	-	92
ENGINE AFTERBURNER DIFFUSER SECTION	-	93
ENGINE DUCTING SYSTEM	-	94
ENGINE DIFFUSER SECTION	-	95
LIGHTING CONTROLS	58	96
FUEL SYSTEM VENT & PRESSURE SYSTEM	59	97
TAIL BUMPER SYSTEM	-	98
GENERAL PERSONNEL EQUIPMENT	71	99
COUNTERMEASURE SET (ALQ-41)	-	100
GUN CAMERA SYSTEM (KS-27C)	-	101

FIGURE I-4. F-111 FAILURE RATE SUMMARY

WUC	SUBSYSTEM NOMENCLATURE	TOTAL FAILURES PER 1,000 FLT HR	ATTACHING POINT FAILURES PER 1,000 FLT HR	IN FLIGHT FAILURES PER 1,000 FLT HR	AIR ABORTS PER 1,000 FLT HR
11	AIRFRAME	296.0	264.0	-	0.1364
13	LANDING GEAR	63.0	10.3	3.35	0.2666
14	FLIGHT CONTROL	120.6	38.4	14.7	0.775
16	ESCAPE CAPSULE	24.7	12.8	2.2	-
23	TURBOJET PWR PLT	235.0	80.7	22.9	1.4198
41	AIR COND & PRESS	26.0	8.2	10.2	0.3162
42	ELECTRICAL POWER	20.4	8.9	1.6	0.0992
44	LIGHTING	26.9	12.8	4.1	0.0248
45	HYDRAULIC & PNEUMATIC POWER	37.6	22.4	2.3	0.2914
46	FUEL	25.4	11.3	10.5	0.6634
47	LIQUID OXYGEN	6.9	1.4	1.7	0.0248
49	FIRE DETECT & EXTINGUISH	2.9	2.3	-	0.1612
51	INSTRUMENTS	29.7	3.6	20.9	0.1612
52	AUTOPILOT	41.6	2.2	20.0	0.8494
61	HF COMMUNICATIONS	14.6	3.2	7.6	0.0
63	UHF COMMUNICATIONS	22.0	6.2	10.8	0.0558
64	INTERPHONE	17.3	3.3	14.7	0.1054
69	COMMUNICATIONS EQPT GENERAL	0.6	0.4	-	-
71	RADIO NAVIGATION	24.6	3.1	16.6	0.0
73	INERTIAL BOMB-NAV	213.0	17.2	156.6	0.558
74	SIGHTING & CONTROL	13.6	4.2	2.4	0.0
75	WEAPONS DELIVERY	155.0	75.7	2.2	0.1302
76	ELECTRONIC COUNTERMEASURES	36.0	2.4	24.8	0.0558
86-97	MISCELLANEOUS	0.8	0.6	0.07	-
AIRCRAFT TOTALS		1455.0	596.0	350.0	6.1

Two-digit WUC level defines major subsystems, such as Airframe or HF Communications. Three-digit WUC defines the primary components within the subsystem, such as HF antenna coupler. The succeeding lower level, four-digit breakdown identifies subassemblies, and five-digit WUC defines the lowest level piece-part in failure recording system.

Four- and five-digit WUC failure data are closely tied to a specific design, manufacturer, and piece-part application and, thus, provide too fine a granularity for projecting advanced concepts. Therefore, the more generalized two- and three-digit summary data are judged to be better suited to this study. It is recognized that summary failure data at the major subsystem levels may introduce some failure rate error; however, since the data are used for relative failure trends and ranking, the effect of finite errors tend to cancel.

Note in Figure I-2 that an apparent incongruity exists, the subsystem "Airframe" indicates negligible failures discovered in flight while "Airframe" ranks 11 in subsystems causing air abort. This is attributable to summarizing and rounding-off the "Total" and "In flight" failures at the two- and three-digit WUC while abort failures are verified by the data system to the lowest identifiable component.

The Boeing data processing system reorders AF 66-1 data to provide reliability data as one output. The reliability data are selective failure sorts performed by computer correlation.

An excerpt from D6-57166-1TN, "Boeing AFM66-1 Electronic Data Processing Programs," provides the reliability failure definition:

"2.7 Reliability Final Printout

The Reliability Final printout is the standard report which is inserted directly into the detailed volumes of the field experience document. Subsystem and component reliability data are compiled directly by automatic processing machines. The first five volumes of the printout contain detailed reliability data at the five digit component level. Volume VI is a summary containing Σ failure rate information at the two, three and four digit subsystem levels for all the systems on the aircraft.

"2.7.1 Application of Failure Data

Some minor limitations should be recognized when applying failure rate data at other than the component (5 digit) level from this printout. The breakdown of the Work Unit Code (as explained in the introduction) identifies the system, subsystem and component. The actual reporting of a malfunction may occur at any of the levels. Depending on the circumstances a malfunction may be called out against a five-digit code component, a four-digit group of components, a three-digit subsystem or a two-digit system.

"The discretion permitted maintenance personnel in reporting malfunctions may lead to possible duplicate recording of failures. The level at which a malfunction is reported could depend on when it is noticed. If the trouble cannot be immediatelv assessed at the proper component level, it may be assigned to a higher level work unit code for troubleshooting. Later the malfunction, after investigation, may be diagnosed to a specific component and reported on another separate form. Thus, a single malfunction can be counted as a failure more than once.

"The failure of a component within a subsystem does not means that the subsystem failed as often. It is possible that a component could fail and yet not cause subsystem failure or some component failures could be secondary failures.

"Duplication of failure rates can be avoided by using the five digit component level data. The user is urged to apply the five-digit level numbers in his computations instead of the four, three, or two digit summaries when the most precise results are desired.

"2.9.2 Definition of Terms

Failure:
As defined in this document, a failure has occurred if a unit of work, other than regular servicing, is required to restore an item to satisfactory condition. Failure count was obtained from AFTO Form 349, subject to the following limitations:

1. Units of work data having the following How Malfunctioned Codes were omitted:

138 - Engine Removed - Engine Modification

141 - Engine Removed - Overseas Preparation

793 - No Defect - TCTO Kits Received by Base Supply

797 - No Defect - Technical Order Not Applicable - Equipment to be Replaced, Modified or Not Installed

799 - No Defect

800 - No Defect - Component Removed and/or Reinstalled to Facilitate Other Maintenance

801 - No Defect - Technical Order Compliance

802 - No Defect - Partial Technical Order Compliance

803 - No Defect - Removed for Time Change

804 - No Defect - Removed for Scheduled Maintenance

811 - No Defect - Class I Modification

812 - No Defect - Associated Equipment Malfunction

"2.(a) If data were taken from an On-Equipment Form, failures were defined by the following "Action Taken" Codes:

F - Repair
G - Repair and/or Replacement of Attaching Parts
K - Calibrated - Adjustment Required
T - Adjust
S - Remove and Reinstall
V - Clean
Z - Corrosion Treatment

"2.(b) If data were taken from a Shop Form, failures were defined by "Action Taken" Codes:

1 - Bench Check - NRTS (Not Repairable This Station) - Repair Not Authorized
2 - Bench Checked - NRTS - Lack of Equipment, Tools or Facilities
3 - Bench Checked - NRTS - Lack of Technical Skills
4 - Bench Checked - NRTS - Lack of Parts
5 - Bench Checked - NRTS - Shop Backlog
6 - Bench Checked - NRTS - Lack of Technical Data

7 - Bench Checked - NRTS - Excess to Base Requirements
8 - Bench Checked - Returned to Depot Facility by Direction of System Manager or Item Manager
9 - Bench Checked - Condemned
A - Bench Checked and Repaired
D - Bench Checked - Transferred to Another Base
F - Repair
G - Repair and/or Replacement of Attaching Parts
K - Calibrated - Adjustment Required
L - Adjust
V - Clean

"Failure Mode:
The mode of failure is defined by the "How Malfunctioned" Code.

"When Discovered Tabulation:
Certain "When Discovered" codes have been combined, as listed below, to define the time at which a discrepancy was discovered.

Before Flight (BF)
A - Before Flight, Abort; Aircrew
B - Before Flight, No Abort; Aircrew
G - Ground Alert, Not Degraded
N - Ground Alert, Degraded

In Flight (IF)
C - In Flight, Abort
D - In Flight, No Abort
P - Functional Check Flight

Between Flights (BTF)
E - After Flight - Aircrew
F - Between Flights - Ground Crew

Inspections (INS)
All "When Discovered" Codes not listed above.

"Aborts:
The following "When Discovered" codes define aborts:

A - Before Flight; Abort, Aircrew
Code "A" represents the cancellation of a scheduled flight prior to takeoff due to unsatisfactory equipment operation.
C - InFlight; Abort
Code "C" represents the termination of a flight prior to successful completion of the assigned mission because of unsatisfactory equipment operation.

"The abort data was screened to ensure that only one abort (flight or ground) was charged per scheduled mission and to determine which component was the prime cause of the aircraft abort.

"NRTS per 1,000 Unit Flight Hours:
Components which require off-base maintenance ("Not Repairable This Station") are indicated by the following Action Taken Codes:

1 - Bench Checked - NRTS - Repair Not Authorized
2 - Bench Checked - NRTS - Lack of Equipment, Tools or Facilities
3 - Bench Checked - NRTS - Lack of Technical Skills
4 - Bench Checked - NRTS - Lack of Parts
5 - Bench Checked - NRTS - Shop Backlog
6 - Bench Checked - NRTS - Lack of Technical Data
7 - Bench Checked - NRTS - Excess to Base Requirements
8 - Bench Checked - Directed Return to Depot Facility

"Condemned per 1,000 Flight Hours;
Action Taken Code 9 (Bench Checked - Condemned) defines a condemned component.

"QPA (Quantity per Aircraft):
The Quantity Per Aircraft indicates the total number of a particular component installed on one aircraft.

"WUC:
The WUC consists of five characters and identifies each aircraft system and component as defined in AFM66-1, paragraph 9-12. A sample printout with a brief explanation of the headings is . . ."

The foregoing Boeing reliability-failure definition is used in processing AFM66-1 data and provides the data base for Figures I-2, I-3 and I-4.

2. Reliability Estimate IIPACS

In addition to providing historical indication of subsystem failure frequency for prioritizing degraded mode analyses, an estimate of the mission reliability of the resulting IIPACS is provided. These data consider the results of the degraded mode analyses, at the subsystem level, and project 1975-85 avionics reliability capability.

Required aircraft functions can be described without considering the physical mechanisms available or required to provide the functions. Reliability requirements can be similarly dictated; however, reliability assessment cannot. When determining the necessity for backup or alternate functional capability based on reliability considerations,

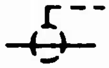
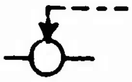
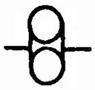
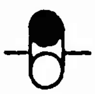
the reliability parameter is determined by direct relation to (or a projection from) a known design and technology base.

Reliability estimates of hardware items to provide the functional requirements necessary for mission accomplishment are given in Figure I-5. These estimates reflect anticipated reliability capability for a 1975-85 time frame based on a reliability survey of electronic manufacturers and reliability growth factors applied to current design. (Historically, electronic reliability has been doubling approximately every 5 years.)

The equipment Mean Time Between Failures (MTBFs) listed are projected from current electronic technology and do not reflect major breakthrough or transition to alternate non-electronic techniques.

Based on the mission phases and flight scenario, defined for this aircraft, a mission reliability analysis of that hardware required to provide necessary mission and flight functions defined by the Degraded Mode Analyses is graphically presented on a mission phase basis in Figures I-6, -7, and -8. The mission reliability analysis identifies mission-essential redundant equipment, equipment that can provide functional backup, and equipment that provide safety of flight functions. It is to be noted that in addition to the electronic equipment necessary for integrated information presentation and control, the diagram also identifies all other major subsystems. The non-electronic subsystems are presented for information, but they are excluded from the mission reliability calculations. In Figures I-6, -7 and -8, this represents all subsystems to the right of the computer complex. Those dependent monitoring subsystems, such as ITEMS and FMAC, are considered to be contained within the prime hardware item and the computer complex. These subsystems, therefore, are not specifically identified in the reliability analysis.

Analysis symbols used are presented below with an explanation of their meaning in the diagrams:

SYMBOL	IDENTIFICATION
	Mission-phase-essential item
	Safety of flight item
	Backup item, not normally energized this phase
	Mission-phase-essential item also providing backup
	Mission-phase-essential item being backed up (arrow head indicates unilateral backup)*
	2 items in redundancy for increased functional reliability
	2 items in redundancy. 1 must work for safety-of-flight (either one)

*Example:
MMR can provide functional backup for TACAN but the converse is not true.

Based on each item's projected MTBF, the mission phase times and degraded mode use, mission reliability estimates of the IIPACS avionics are calculated to be:

Mission Phase	Duration (Minutes)	Avionic Reliability
Start	5	0.99988
Takeoff	5	0.99970
Climb	30	0.99078
Rendezvous	10	0.99948
Cruise	60	0.98887
Loiter	40	0.99324
Air-Air Combat	20	0.99639
Refuel	20	0.99764
Penetrate	20	0.99539
Air-Ground Combat	50	0.98725
Approach & Land	10	0.99956
Mission Total	270	0.9493

FIGURE I-5

PROJECTED SUBSYSTEM RELIABILITY

SUBSYSTEM EQUIPMENT	1975-1985 Flight MTBF (Hrs)
FIRE CONTROL SUBSYSTEM	
Multimode Radar	600
Low Light Level TV	1,000
Forward Looking Infrared	500
LASER Ranger	1,500
Bomb Damage Assessment	650
NAVIGATION SUBSYSTEM	
Inertial Platform	2,000 (ea)
Heading Attitude Ref System	3,000
Satellite Navigation System	2,500
Instrument Landing System	5,000
Radio Altimeter	4,000
TACAN	3,000
COMMUNICATION & IDENTIFICATION	
Collision Avoidance	2,000
HF Radio	2,000
SHF Spread Spectrum	1,000 (ea)
Intercom	4,000
IFF Air-Air	1,200
IFF Air-Ground	4,000
PENETRATION AIDS	
Radar Home and Warn	1,500
ECM Jammer	1,000
Infrared Warning	500
Infrared Jammer	1,000
Chaff-Flare Dispenser	500
CONTROLS AND DISPLAYS	
Head-Up Display	2,500
Vertical Situation Display	2,500
Horizontal Situation	1,000
Multipresentation Display	1,000
Integrated Keyboard	5,000
CENTRAL COMPUTER	
Computer	4,000

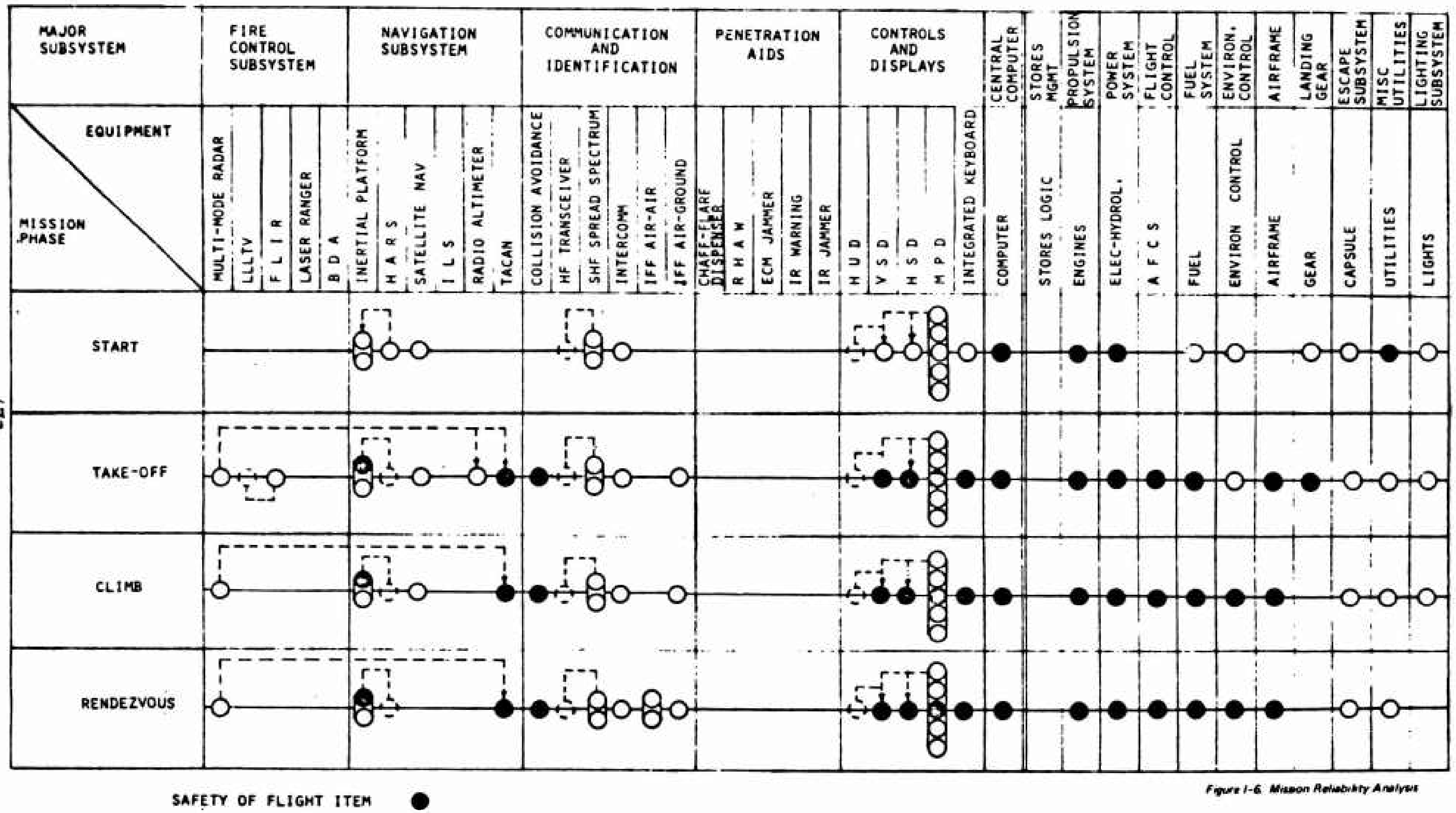
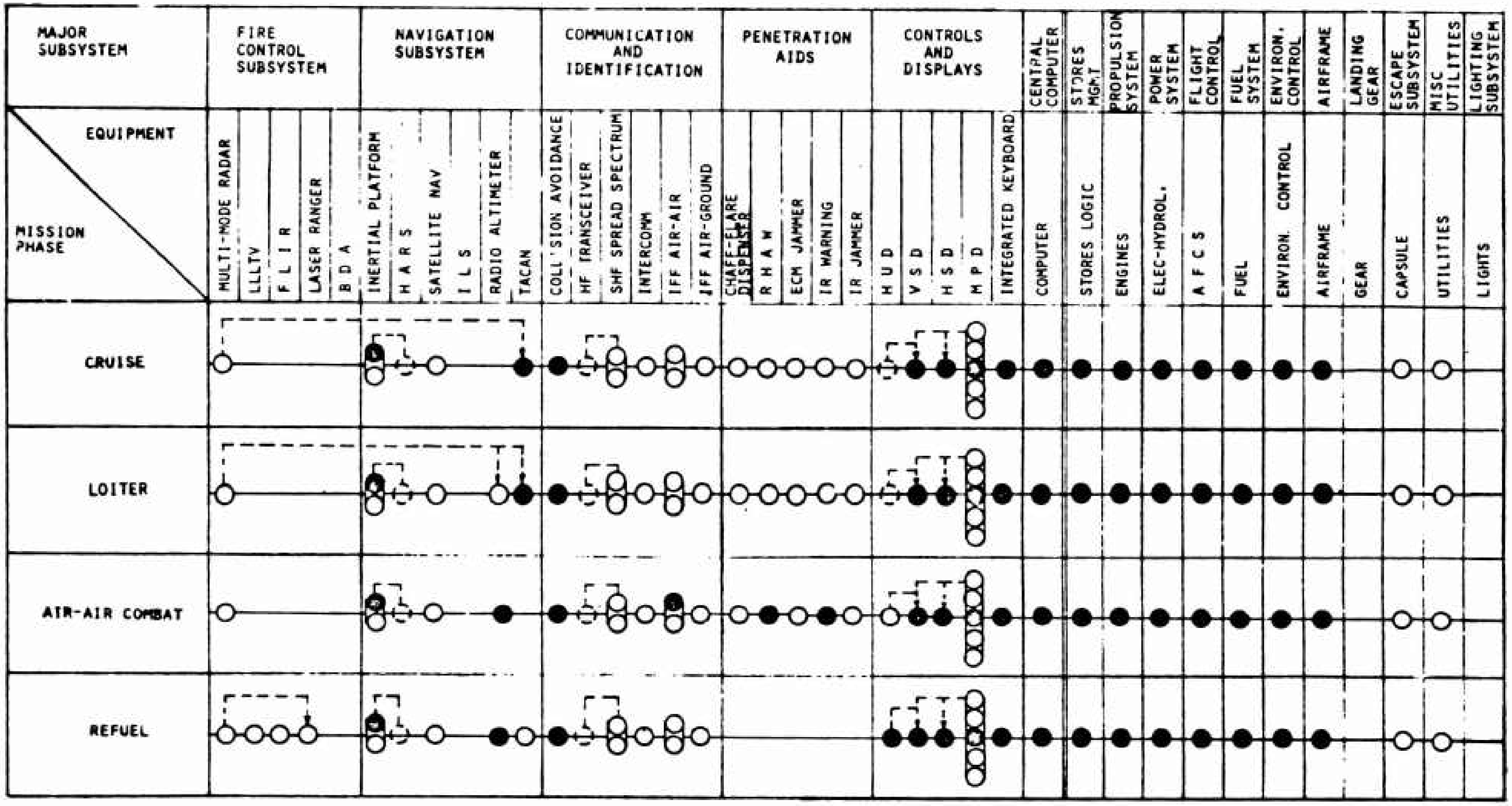


Figure I-6. Mission Reliability Analysis



SAFETY OF FLIGHT ITEM ●

Figure I-7. Mission Reliability Analysis

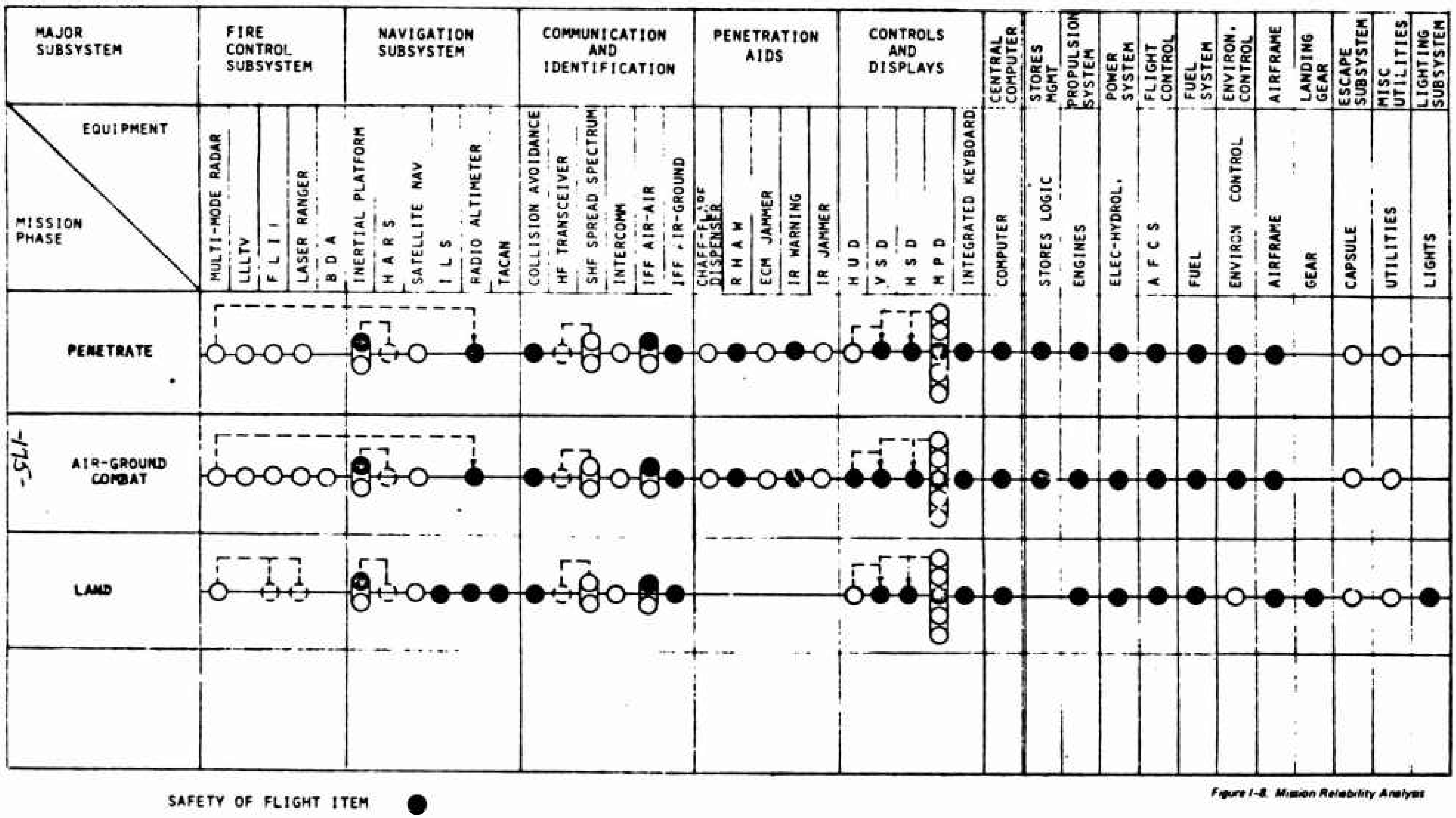


Figure I-8. Mission Reliability Analysis

APPENDIX II

LIST OF TRIPS

Name	Facility	Contact	Subject	Date
J. Bloomfield D. Lawrence	Control Data Corp. Minneapolis, Minn.	S. J. Skiba, Program Mgr.	Industry Survey - Adv. Airborne Systems	7/20
J. Bloomfield D. Lawrence J. Premselaar	UNIVAC Minneapolis, Minn.	W. D. Miller, Mgr., AF Avionics J. R. Erhardt, Sys. Design Engr. E. C. Joseph, Staff Scientist F. B. Lowe, Dir. of Marketing	Industry Survey - Adv. Airborne Systems	7/20
J. Bloomfield D. Lawrence J. Premselaar	FDL, Dayton	R. D. Alberts - AVL H. W. Basham - FDCL R. E. Burain - Bunker RAMO R. R. Davis - FDCR R. Green - FDCL R. Guth - FDCL J. H. Kearn - FDCR Lt.Col. Knox - FDCR Lt. N. A. Kopchick - FDCR A. J. Longiaru- FDCS J. Mysing - AVWC D. Schroll - ASNMC-10 Lt.Col. Studabaker- AVL R. S. Vokits-ASNMC-10 Lt. J. K. Warner - ASNMC-10	IIPACS-1 briefing	7/21
D. Lawrence J. Premselaar	Loral Electronic Systems, The Bronx, N. Y.	L. Levene, Dep. Chief Engr., Electronic Warfare	Industry Survey - Radar Homing Warning	7/22

Name	Facility	Contact	Subject	Date
		A. I. Paley, Product Line Mgr., Adv. Info. & Display Systems		
D. Lawrence J. Premselaar	Bendix Teterboro, N. J.	J. Koltz, Sales, Special Products	Obtain information on armament control systems concepts	7/22
D. Lawrence J. Premselaar	NADC-Johnsville	J. Caswell - AMRD R. Crosbie - AMRD R. Decker - SAED W. Miller - SAED J. Nelson - LSEH-1 W. Ogden - SAED H. Piranian- SAED	IIPACS-1 briefing	7/23
D. Lawrence J. Premselaar	HIPAAS Ad Hoc Comm. Washington, D. C.	K. Guttman - AIR-330C NAVAIR Col. A. McBarron - AIR-03M NAVAIR J. Plunkert - AIR-3032E NAVAIR W. Sparrow - AIR-3032G NAVAIR	IIPACS-1 presentation	7/24
D. Lawrence J. Premselaar	Crew Systems Div. Washington, D. C.	Capt. W. E. Nowers, Dir. CDR R. J. Hartranft	IIPACS-1 presentation	7/24
D. Lawrence J. Premselaar	Avionics Division Washington, D. C.	J. Wolin, Head, Integ. Instrumentation & Display Section	IIPACS-1 presentation	7/24
J. Hatcher D. Lawrence J. Premselaar	Westinghouse Elec. Co., Defense & Space Ctr., Baltimore	R. Sima, B-57 LLLTV Prog. Mgr. D. Boybns, EVS Systems J. Holthaus, Crewstations Hdw. Dev. & Mockup T. Stinnett, Cockpit Display Analysis	Industry Survey - State of art - LLLTV, FLIR, LASER, Auto. Tgt. Recognition & Display Design Concepts	7/27

Name	Facility	Contact	Subject	Date
		Dr. G. Tisdale, Mgr., Information Tech.		
J. Hatcher D. Lawrence J. Premselaar	Raytheon Co. Bedford, Mass.	R. Price, Avionics Tactical Fighters D. Mathews, Avionics, Bombers W. Vasel, Design Study, Missiles P. Mender, Mktg. Mgr., Avionics Systems	Industry Survey - Phased Array Radars for Adv. Fighters	7/28
J. Hatcher	Collins Radio Cedar Rapids, Ia.	D. Valentine, Asst. Proj. Mgr., CNI J. Andrews, Staff Engr., Sat. Comm. K. Black, Staff Engr , UHF R. Vanderhamm, Relia-bility K. Rutherford, Staff Engr., IFF D. Schmidt, Flt. Inst./Displays C. Fenwick, Staff Engr., Integrated Keyboard Controls H. Schweighofer, Staff Engr., CRT Adv. Design	Industry Survey - State of art - Adv. Comm/Ident Systems & Flight Instruments	7/29
D. Lawrence J. Premselaar	Eglin AFB, Fla.	R. Compton - ADLY M. Flyn - ADLY	Information relative to weapon system management	7/29

Name	Facility	Contact	Subject	Date
J. Bloomfield J. Hatcher D. Lawrence J. Premselaar	Texas Instruments Dallas, Texas	B. List, Dr., Systems & Info Science Lab. C. Breadnay, Avionics Systems G. Bandy, Adv. Radars J. Seveorin, Space Sys. J. [illegible]xon, Adv. FLIR B. Bocha, Equip. Gp., CNI	Industry survey - Adv. radars, FLIRs and airborne computers	7/30
J. Hatcher D. Lawrence J. Premselaar	Litton Systems, Inc Guidance & Control Sys., Woodland Hills, Calif.	J. Murphy, Augmented Sys. Adv. Prog. Mgr.	Industry survey - Adv. Navigation Systems	7/31
J. Hatcher D. Lawrence J. Premselaar	Hughes Aircraft Culver City, Calif.	L. Seeberger, Mgr., Display Sys. Lab. W. Carel, H. F., & Func. Design J. Heard, Systems Design	Industry survey- Adv. Control/Display Concepts	7/31

APPENDIX III

NAVIGATION SYSTEMS

1. INTRODUCTION

This section describes the basic navigation system for 1980 all-weather tactical combat aircraft. The system selection is based on detail performance data for those postulated theater-of-operation systems in the 1980 inventory. Integration of these subsystems for the tactical fighter aircraft by means of the computer software is a most pressing consideration.

2. SYSTEM DESCRIPTION

a. Operational Description

The classes of navigation systems available for tactical fighter aircraft are comprised of many sensors as shown in Figure III-1. A complete system using Figure III-1 sensors is shown in the composite diagram on Figure III-2. Hyperbolic systems are considered but not included in aircraft equipment lists. Hyperbolic systems would be included if expected trend toward satellite navigation does not materialize.

The following discussion will be limited to the navigation system required for precision navigation and weapon delivery: (1) Free Inertial/Doppler Inertial, (2) Direct Ranging, (3) Hyperbolic, and (4) Satellite.

3. FREE INERTIAL/DOPPLER-INERTIAL NAVIGATION

One of the simplest forms of navigation systems is the free inertial system. A block diagram of the system is shown in Figure III-3. The system provides basic navigation data to the flight crew. The accuracy of the information depends on the quality of the inertial unit. This type system, however, exhibits a basic error growth rate shown in Figure III-4. (Note the 84-minute Schuler oscillation). The average error growth rate of such a system is on the order of 0.1 to 0.5 nmi per hour CEP. The instantaneous velocity error may be as much as 1 foot per second (1 sigma each axis) because of the Schuler oscillation. Thus, both the navigational accuracy and the velocity error transferred into a weapon delivery system are a function of both the mission time and the time within the Schuler oscillation.

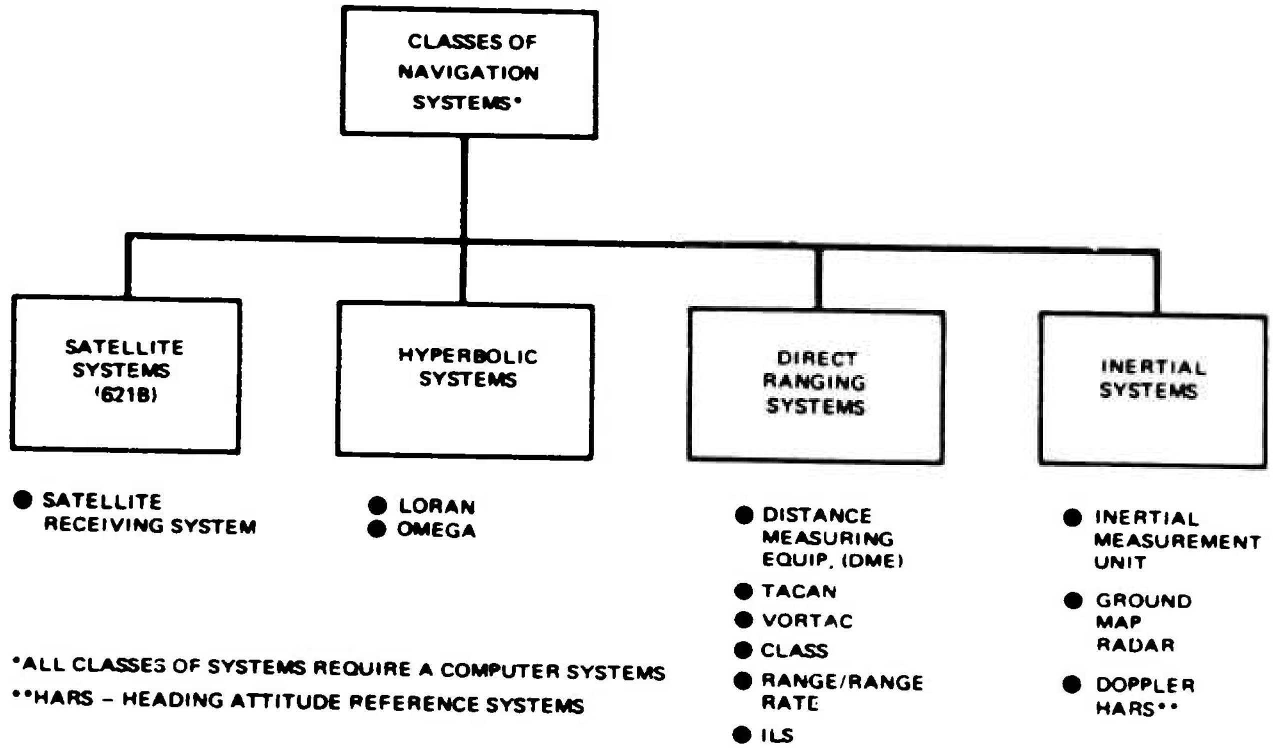


Figure III-1. Classes of Navigation Systems Available for Tactical Combat Aircraft

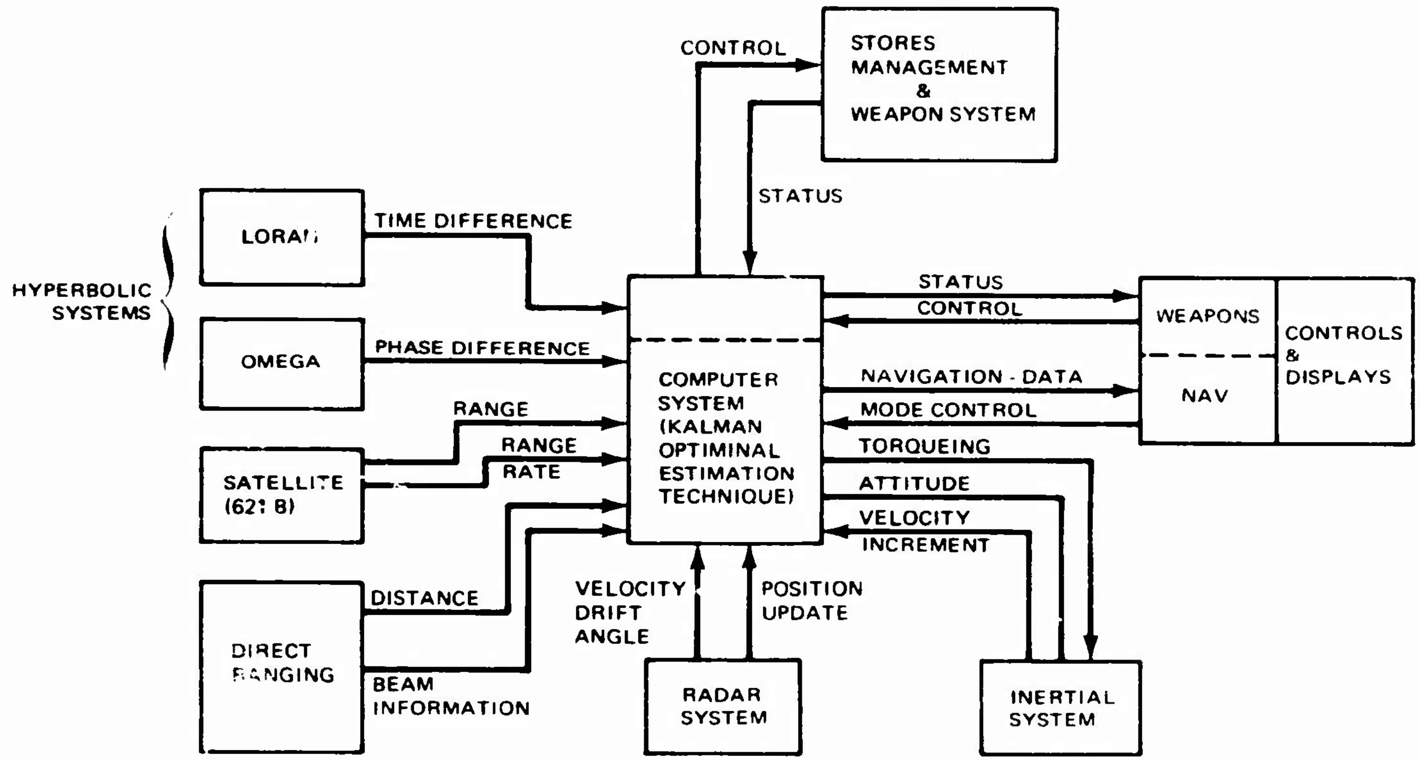
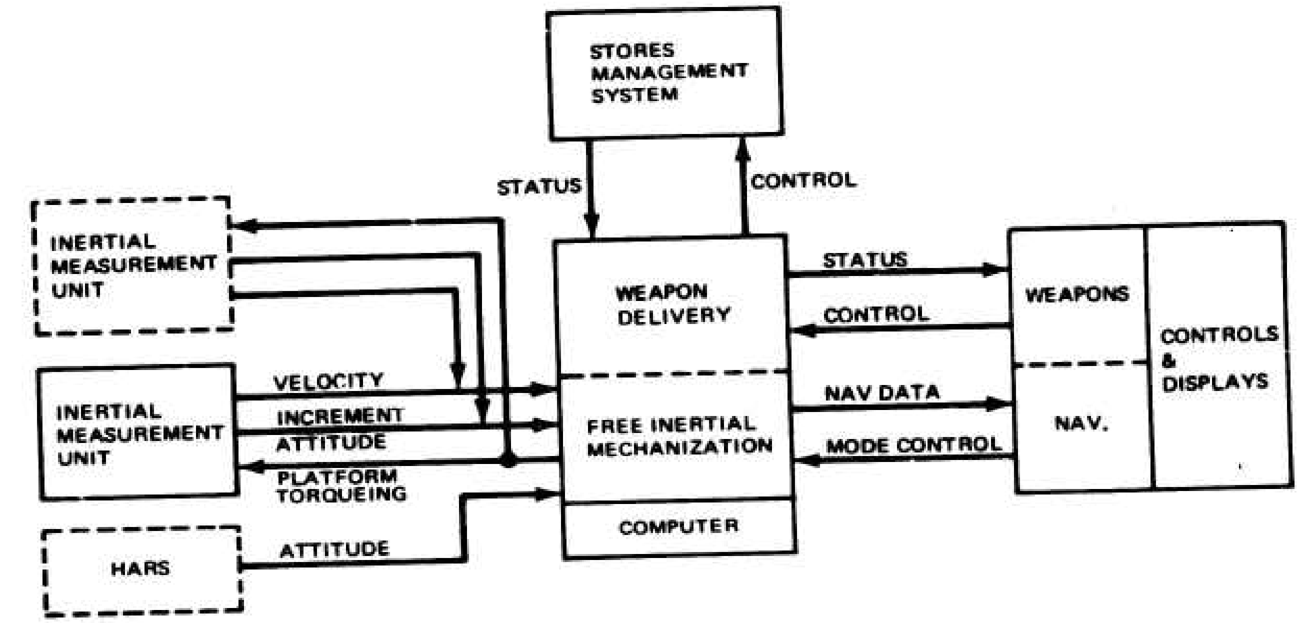


Figure III-2. Composite Navigation Systems Block Function Diagram



NOTE:
THE UNITS SHOWN DOTTED ARE
REDUNDANT, BACKUP UNITS

Figure III-3. Free Inertial Navigation System Functional Block Diagram

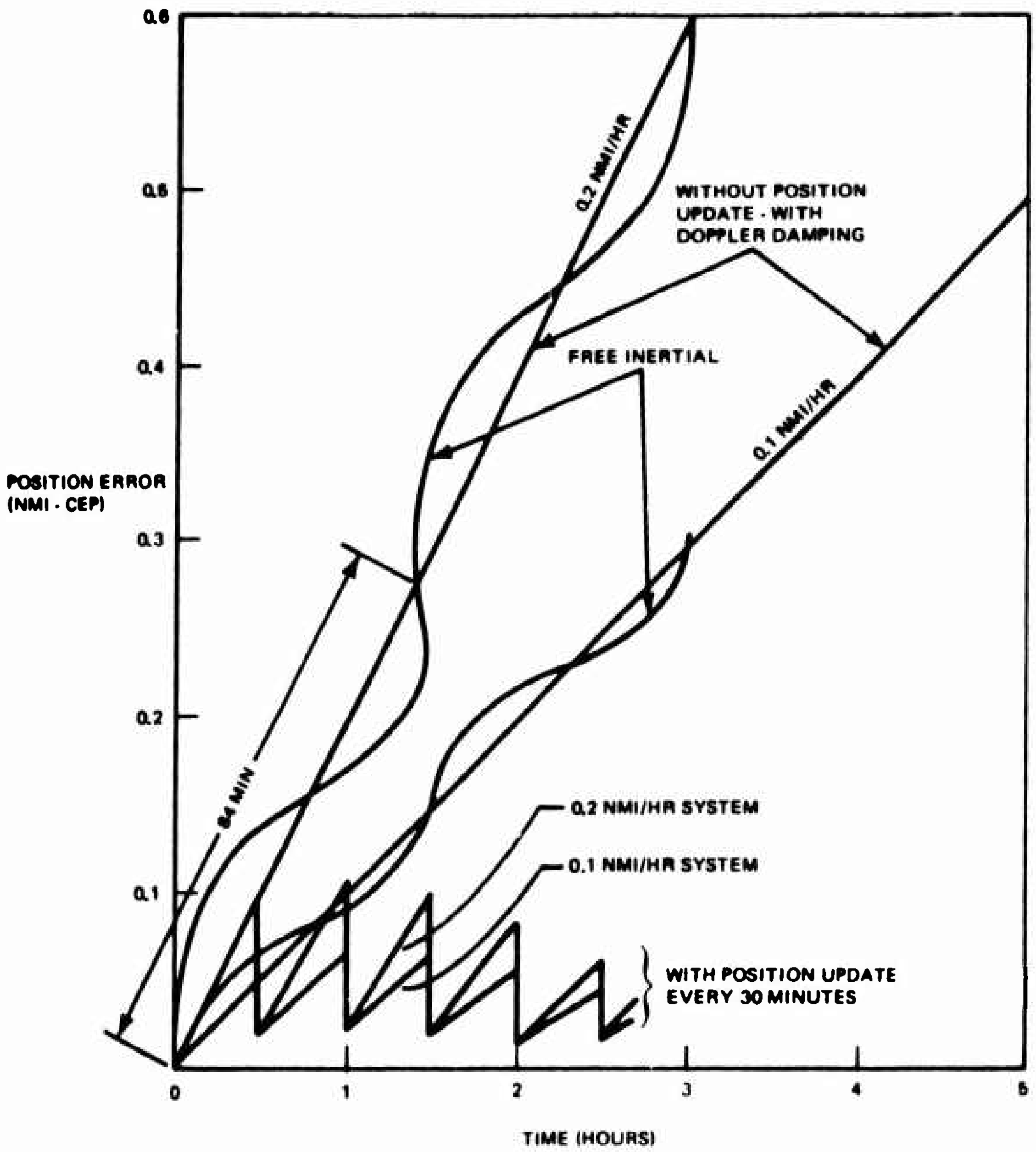


Figure III-4. Doppler Inertial Performance with Position Updates

The addition of Doppler velocity damping to the basic navigation loop (Figure III-5) eliminates the Schuler oscillation. However, the error growth still increases as shown in Figure III-4. The addition of periodic position updating by, for example, a ground map radar to the navigation mechanization resets the position errors at each update period.

Navigation mechanizations for Doppler-inertial systems with updates from external references uses a Kalman estimation technique. This technique permits optimal use, in the least squares sense, of all data in the system. The performance of the total system is thereby improved. Both the position error and the error growth rate are reduced after two to three update periods, because the estimator calibrates bias errors. The amount of improvement is a function of the accuracy of the position update, the accuracy of the Doppler information, and the basic accuracy of the inertial measurement unit. The Doppler characteristics are shown in Table III-1.

Table III-1. Doppler or Error Models

Error Parameters	Doppler
Scale Factor Bias (%)	0.07
Boresight Bias (min)	3.9
Fluctuation Noise Ground Speed (ft/sec)	1.72

The block diagram of Figure III-5 shows the basic inertial sensors in a redundant configuration. The attitude outputs of each of the inertial units are compared in two-out-of-three voting schemes to provide a criteria for malfunction detection and unit selection.

A backup-dead reckoning mode is implemented by using the heading outputs from the HARS and the velocity data from the Doppler sensors. These outputs, when compared to the position computations from each inertial measurement unit, provide a two-out-of-three voting scheme to assess the quality of the total navigation system.

4. DIRECT RANGING SYSTEMS

The VORTAC and ILS systems are generally used in the CONUS with some limited application in the threater of operation. Generally, these systems are considered to be

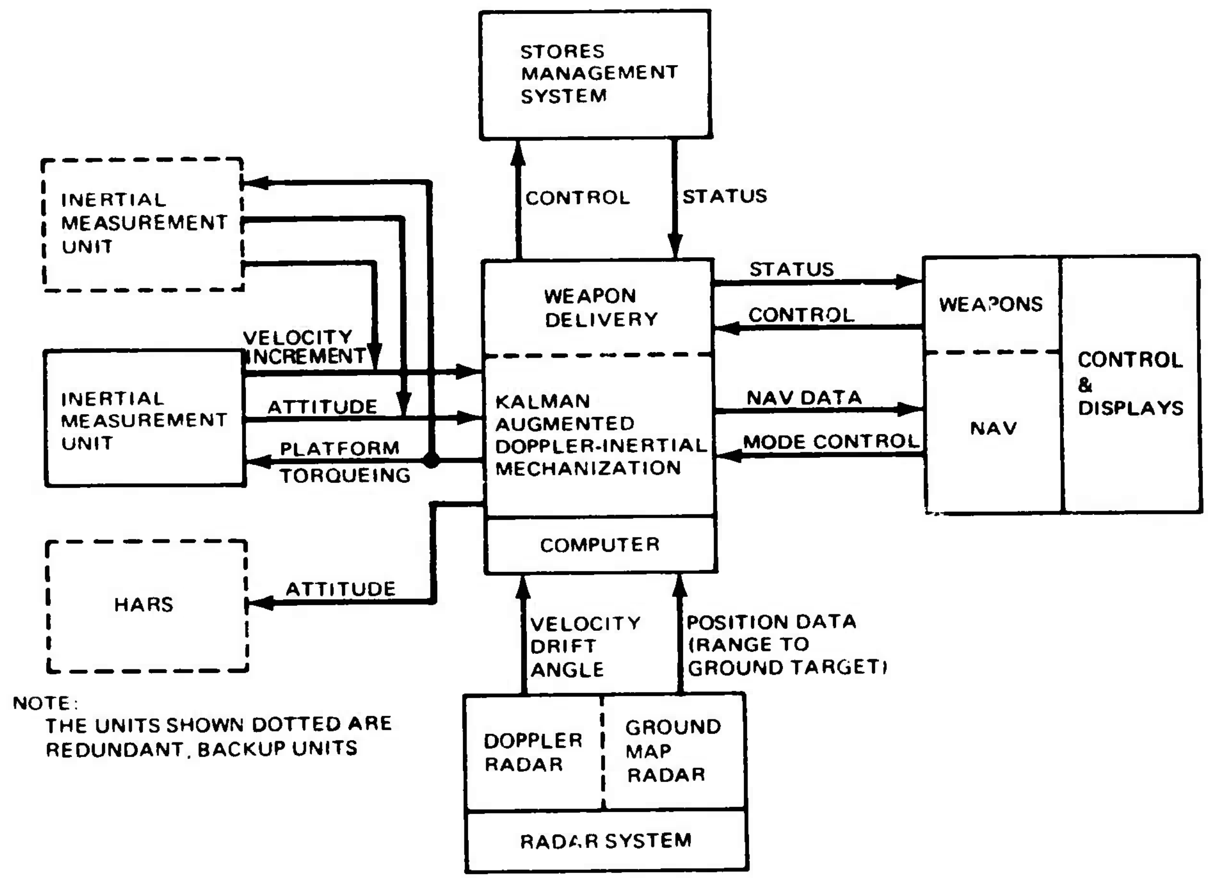


Figure III-5. Doppler-Inertial Functional Block Diagram with Position Updating

aircraft guidance sensors used for routine point-to-point navigation and for the terminal landing area. The type of ground installations necessary for VORTAC are not practical for a fluid tactical ground war. These systems are not used on the outbound leg of a tactical mission; however, they may be used to facilitate recovery of the aircraft on the return leg of the mission.

Direct ranging systems under some conditions apply to tactical combat aircraft missions for navigation. The constraint imposed on these systems is the requirement for ground radio equipment. In a fluid battle situation, systems such as TACAN and VORTAC are useful only as recovery navigational aids near established air bases. Systems such as Close Attack Support System (CLASS) and Range/Range Rate require ground forward observers or ground transponders. The concepts for both CLASS and the Range/Range Rate systems are shown in Figures III-6 and III-7 respectively.

Figure III-6 shows that the CLASS concept requires that the forward controller have an accurate knowledge of his position relative to the target. The aircraft relative to the forward controller is located by successively interrogating a transponder carried by the forward controller. Then, a trialateration computation is made to fix the aircraft relative to the forward controller and, therefore, relative to the target. A block diagram of CLASS is shown in Figure III-8. Recent testing at Holloman indicates position accuracies determinations are achievable that permit accurate blind bombing of targets.

The Distance Measuring Equipment (DME) or range and range-rate systems are generally the same as the CLASS concept. The radio net is shown in conceptual form in Figure III-7. The flight through the ground transponder net permits determination of accurate range and range rate information relative to the transponder. The range and range rate information is used in a Kalman optimal estimator to calibrate the navigation system.

5. HYPERBOLIC SYSTEM

The two most familiar hyperbolic navigational aids are the LORAN and OMEGA systems. The LORAN system net operates three or more transmitters in the 100-KHz frequency band (LORAN C and D). One transmitter is a master station. The other stations are slaved to the master station time-wise. Figure III-9 shows the loci for constant time differences relative to the master slave pair. The intersection of the hyperbolae defines range relative to the station complex. A receiver system that can measure time of arrival difference from each of the master-slave pairs will provide position information at the intersection of

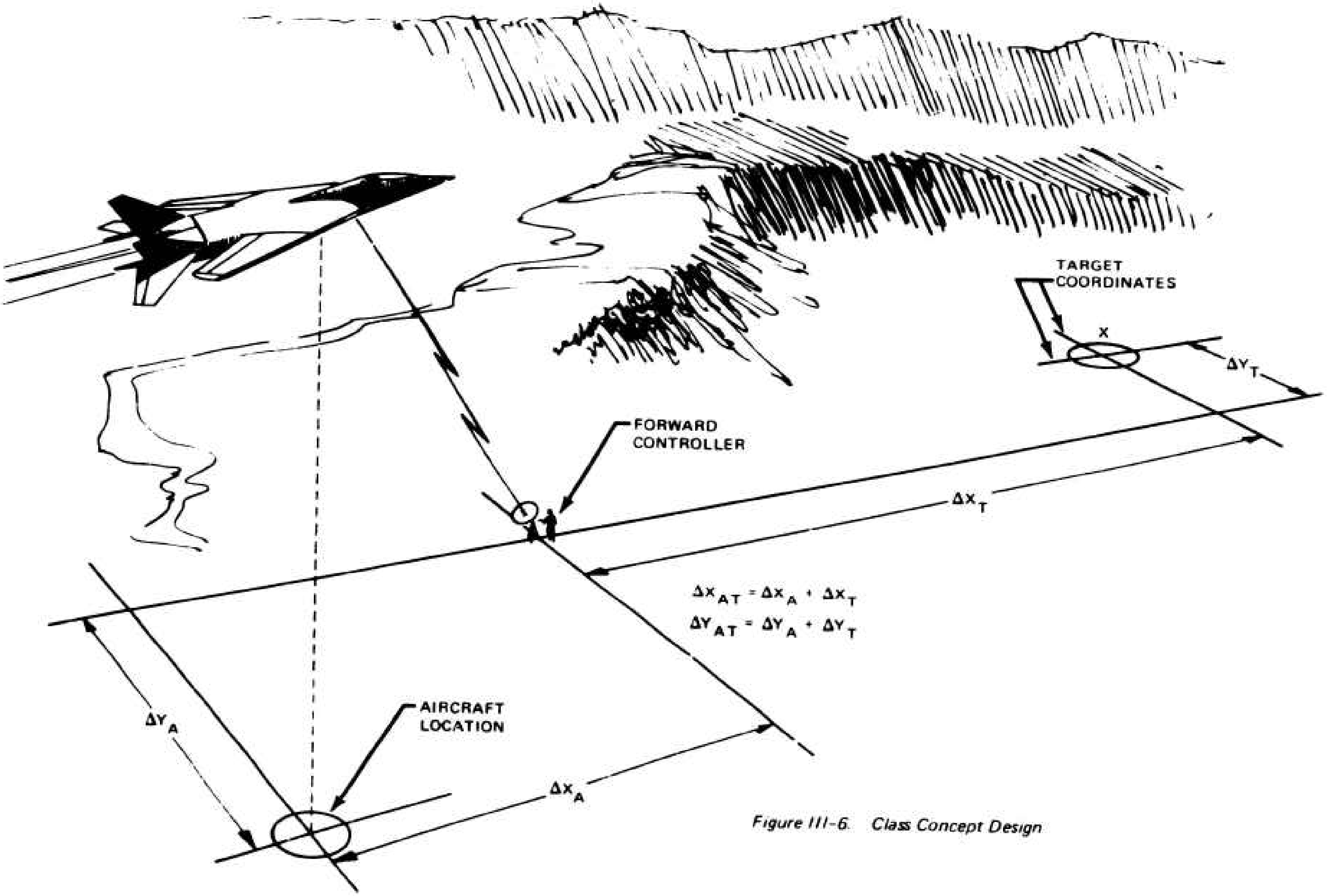


Figure III-6. Class Concept Design

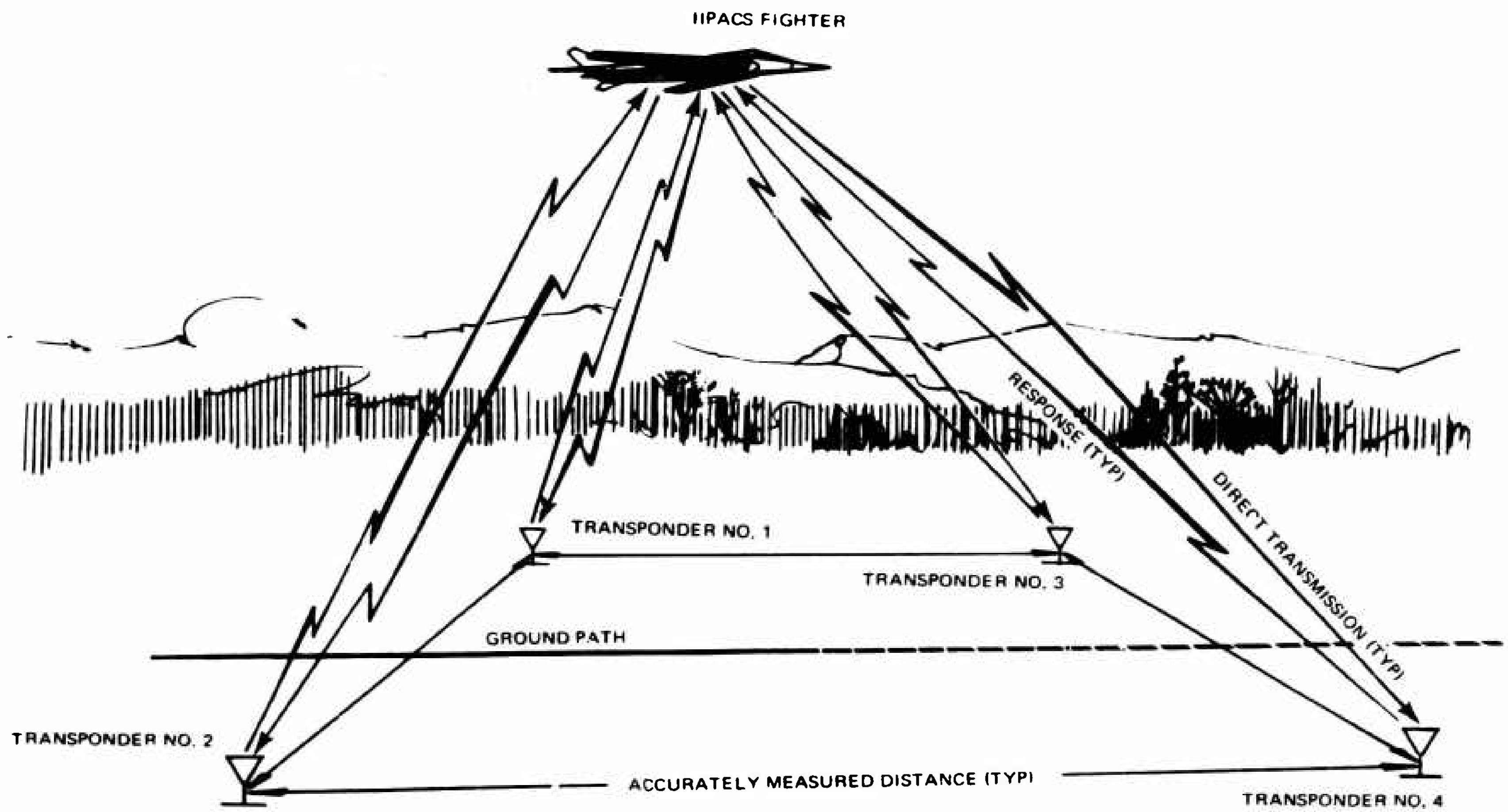


Figure III-7. Direct Ranging (DME) Concept - Position Fixing

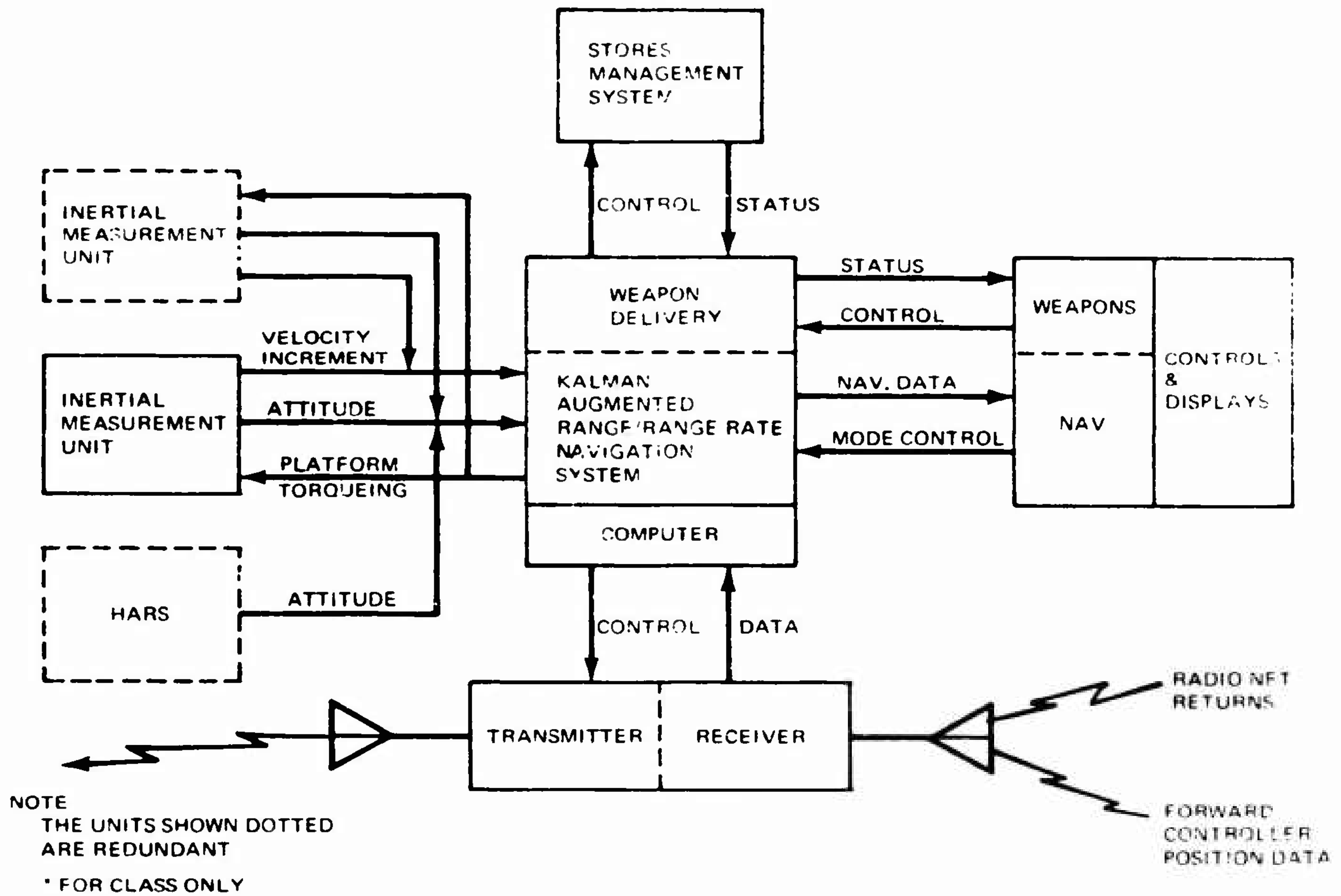


Figure III-8. Range/Range Rate Functional Block Diagram

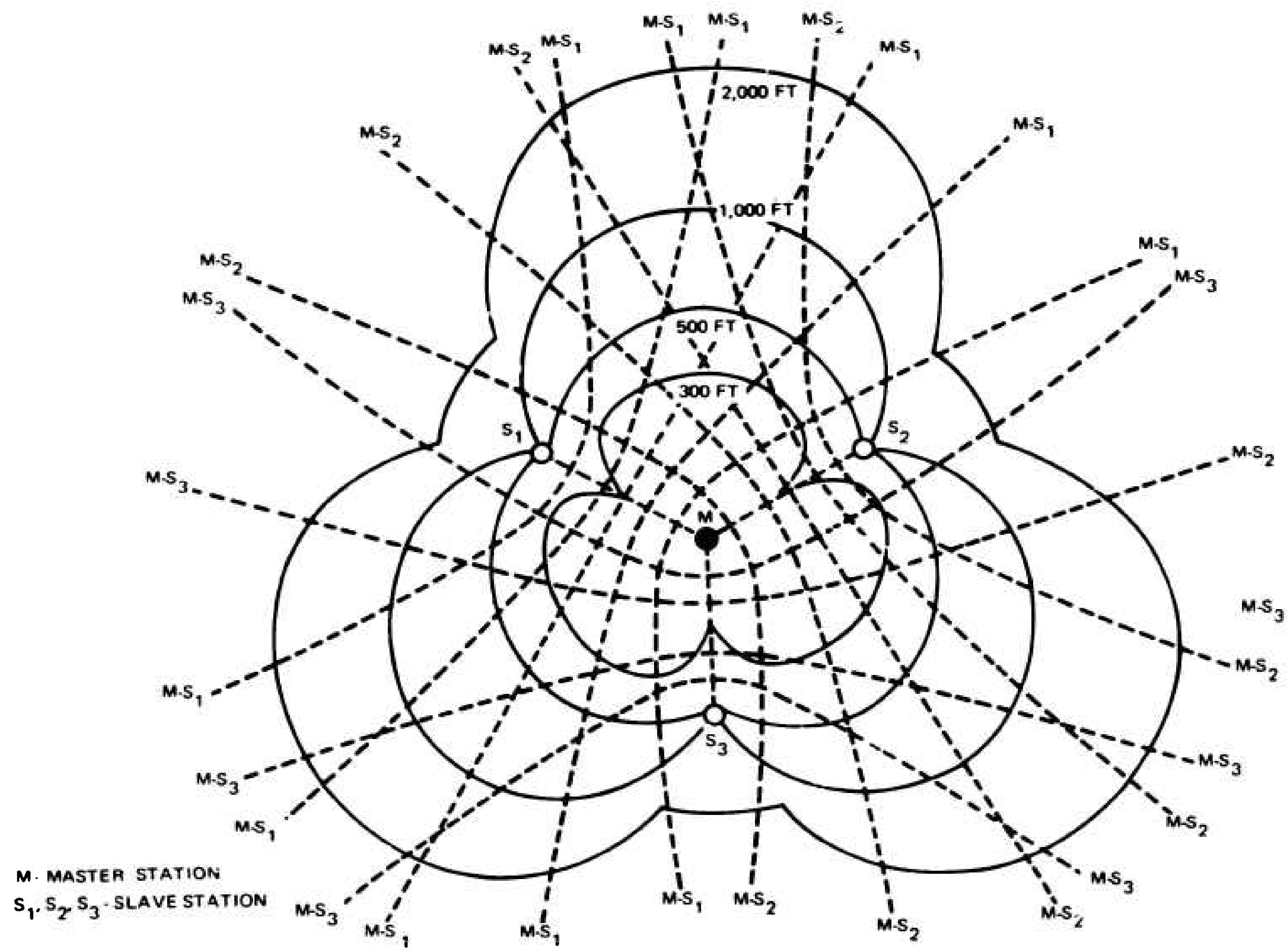


Figure III-9. Loran Accuracy Contours – Symmetric Configuration

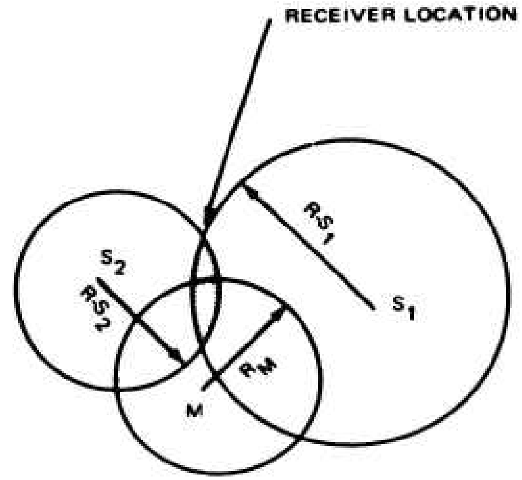
two hyperbolae. Then LORAN chains are available, an aircraft can find its position to better than 1,500 feet (90th percentile), depending on the location, or the receiver relative to the LORAN chain and the geometry of the chain itself. The dominant errors in the LORAN system are propagation errors, timing errors, sky wave errors and velocity tracking errors (in aircraft only). The errors are modeled as observation errors in the Kalman estimator.

A RHO-RHO system of direct ranging to any station in the LORAN chain is implemented if the receiver has an accurate (atomic) clock. The receiver clock is synchronized with the master clock before the mission and all time differences are determined relative to the receiver clock. This time difference is the range to the station. Loci of constant time difference are circles relative to the transmitter. Two intersecting circles provide two apparent locations of the receiver (See Figure III-10). Direct ranging from a third station eliminates the ambiguity. In general, all three range circles will not intersect at one point because of errors in the system. This results in a position uncertainty. This position uncertainty is minimi ed by modeling the system errors in a Kalman estimator.

The disadvantage of the LORAN system is the limited coverage on a world-wide basis. The OMEGA system is being put into operation by the Navy to eliminate this problem in radio navigational aids. Four transmitting stations, time synchronized, are now in operation providing limited world-wide coverage. These stations are at Aldra, Norway; Forresport, New York; Hawaii, and Trinidad. By 1972, the Navy expects to have four additional transmitters operating to complete the world-wide coverage. In addition, the power outputs of the existing transmitters will be increased.

The OMEGA stations transmit at 10.2 KHz and 13.6 KHz in assigned and identifiable time slots. The OMEGA receiver measures the phase difference from any two stations. The lines of constant phase from any two stations form hyperbolae similar to those of the LORAN system. Two pairs of stations, as in the LORAN system, are needed to form intersecting hyperbolae to fix the location of the receiver.

The accuracy of the system is about 1 nmi during the day and 2 nmi at night, after the major error sources are compensated for in the computer. These error sources are propogation errors due to the land/sea conductivity differences, diurnal effects due to changes in the ionosphere D layer composition as a function of the sun angle in the propagation path, magnetic variation errors, latitude errors (aircraft only). As in the LORAN system, the errors are modeled in the Kalman estimator to improve system performance.



NOTE: LORAN SHADED AREA IS THE UNCERTAINTY IN RECEIVER LOCATION DUE TO SYSTEM ERRORS

M = MASTER STATION
S.S. = SLAVE STATIONS

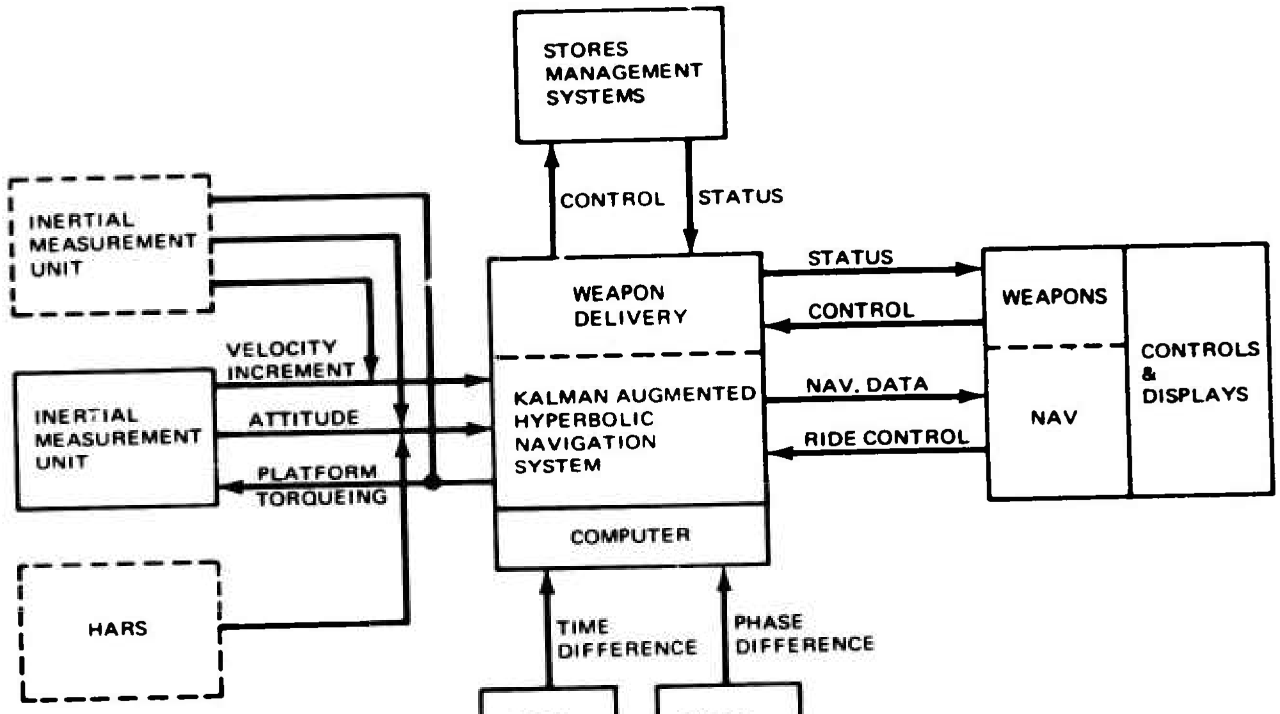
R-S_1 - RANGE FROM S_1 TO RECEIVER
R-S_2 - RANGE FROM S_2 TO RECEIVER
R_M - RANGE FROM M TO RECEIVER

Figure III-10. RHO-RHO Ranging Concept

A block diagram for the hyperbolic type of navigational aids in combination with the Doppler-inertial system is shown in Figure III-11. The inertial system with its quiet velocity channels smoothes the noisy and sometimes erroneous signals from the radio receivers. On the other hand, the error growth rate (discussed in the section on inertial systems) is bounded effectively by the radio aids. Use of these sensors in a Kalman estimator improves the performance of each sensor. For Doppler-Inertial-LORAN-System, error bounds down to 300 feet CEP are achievable for favorable receiver/station geometries. The Doppler-Inertial OMEGA error bounds are between 0.5 to 1.0 nmi CEP.

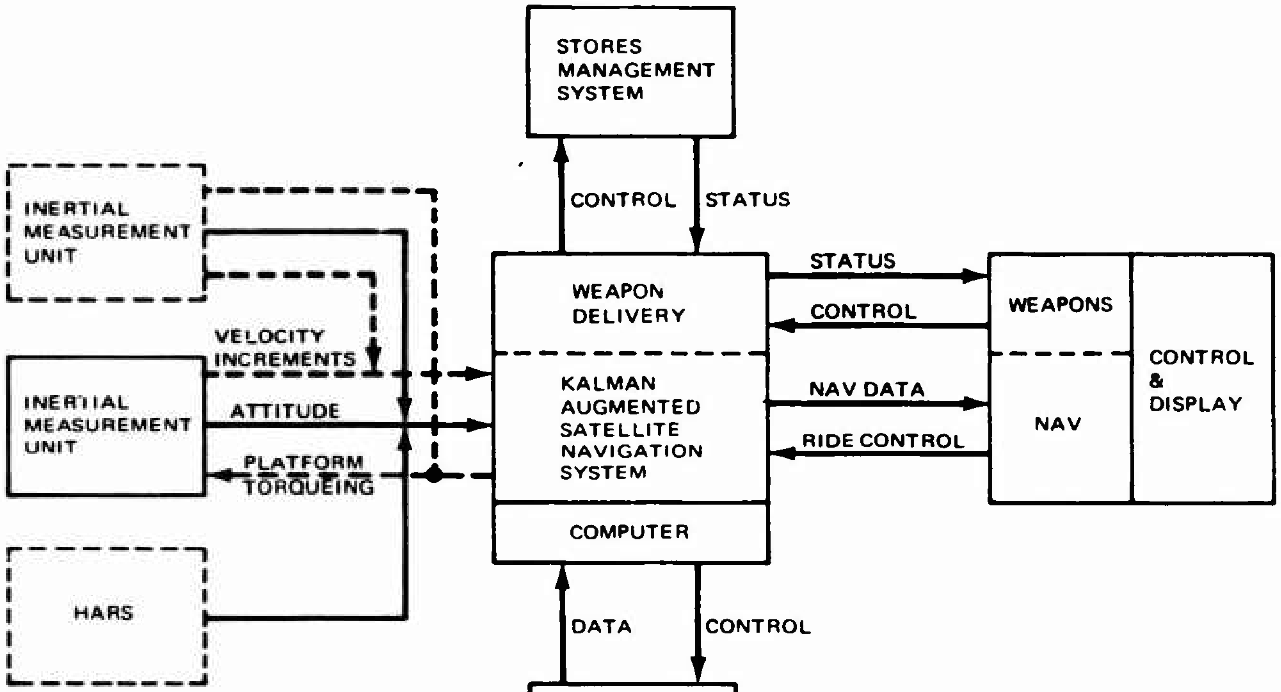
6. SATELLITE SYSTEMS (NAVSAT - 621B)

The Air Force 621B NAVSAT system provides navigation data to any user within the radar range of the satellite cluster. Three satellites are needed for a user to determine position information. Four satellites provide the capability for the user to also determine altitude above the terrain. Specific details of the system are classified. The system accuracy will permit the user to determine position with errors between 50 and 500 feet CEP, depending on the satellite/user spatial geometry. The user is also able to determine the velocity of the aircraft to less than 0.5 feet per second. A block diagram is shown in Figure III-12.



NOTE:
THE UNITS SHOWN DOTTED ARE
REDUNDANT, BACKUP UNITS

Figure III-11. Functional Block Diagram – Hyperbolic Radio Navigational Aids



NOTE:
DOTTED UNITS PROVIDE REDUNDANT NAVIGATION DATA. ATTITUDE IS USED FOR AUTO PILOT & RADAR STABILIZATION

Figure III-12. Satellite Navigation Functional Block Diagram

REFERENCES

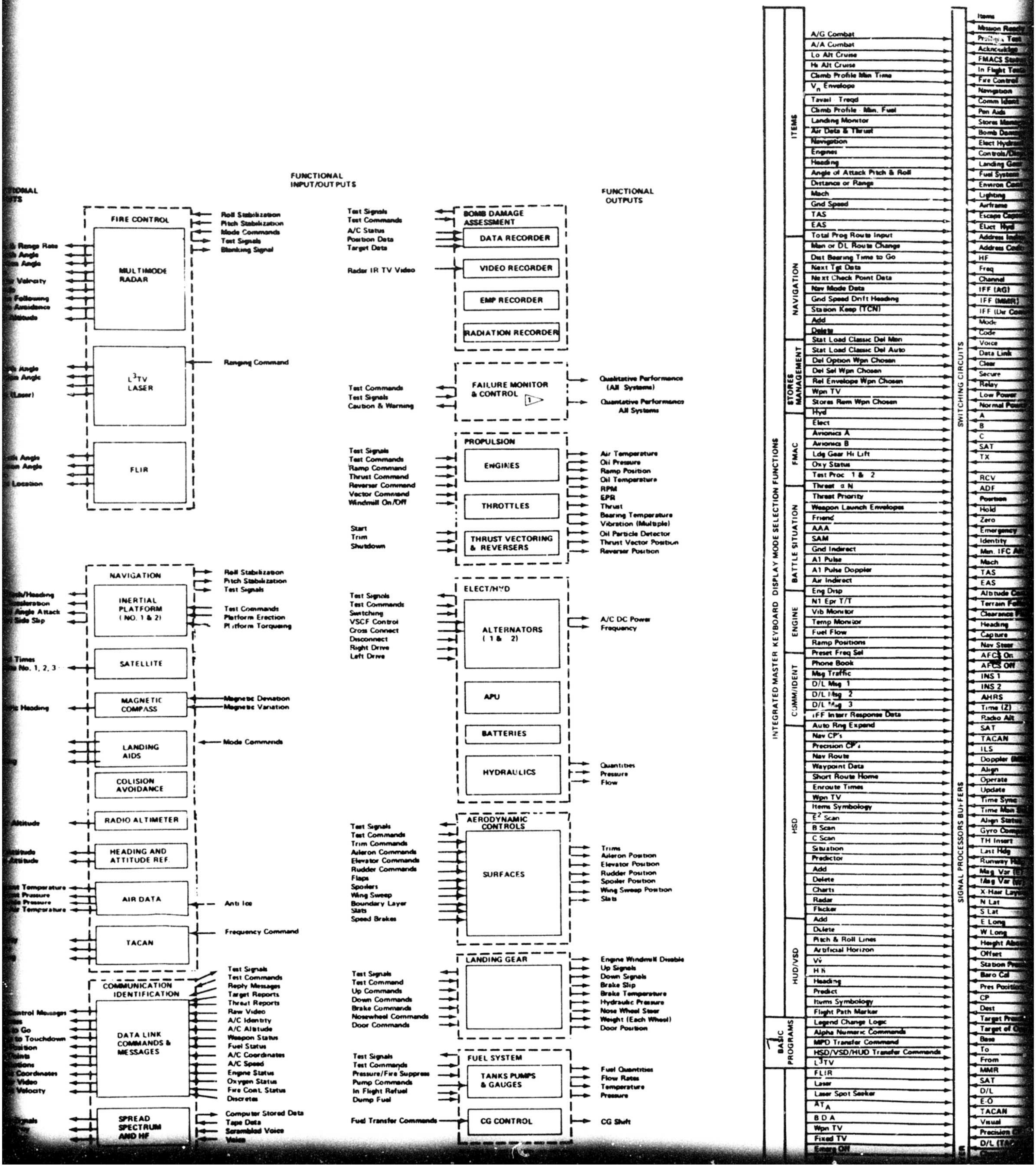
1. Scheurell, J. E. Proposed Binary Intersystem Transmission Characteristic - Reference Data and Rationale, D6-23849-1, The Boeing Company, October 7, 1969.

2. Computer-Display Feasibility Study for Flight Performance Optimization, AFFDL-TR-68-125, October 1968.

3. Morgan, Cook, Chapanis, and Lund. Human Engineering Guide to Equipment Design, McGraw-Hill Book Co., Inc., 1963.

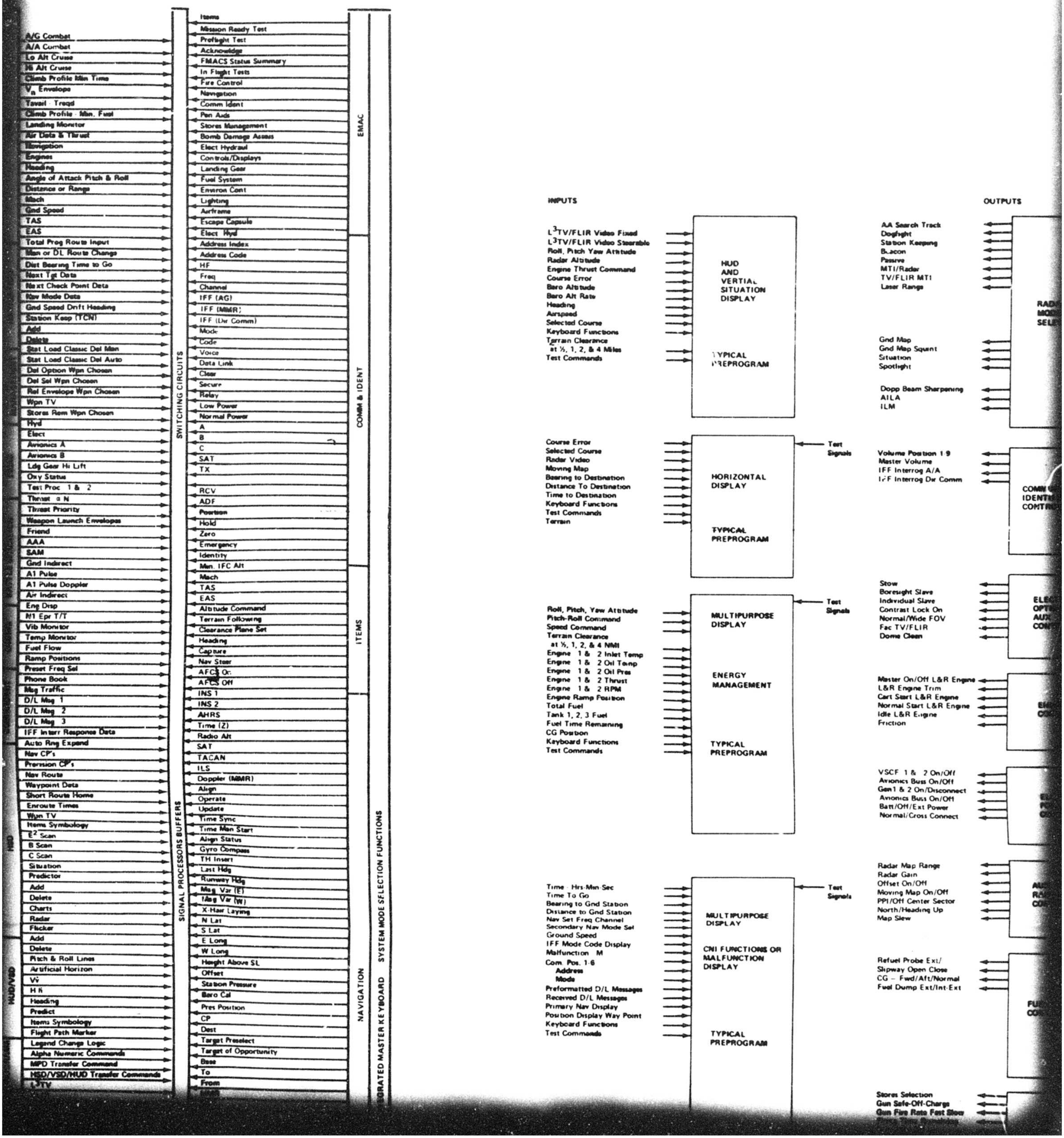
4. Brumaghim. A Review of Radar, Television, and Infrared Sensor Displays as Aids to Closed-Curtain Flight Capability of the B-52, D3-7178, The Boeing Company, September 23, 1968.

5. Hall, Way, and Belyea. Design and Evaluation of Primary Hand Controllers for Fighter Aircraft, AFFDL-TR-71-16, December 1970.



FUNCTIONAL INPUT/OUTPUTS
FUNCTIONAL OUTPUTS
FIRE CONTROL
MULTIMODE RADAR
Roll Stabilization
Pitch Stabilization
Mode Commands
Test Signals
Blanking Signal
& Range Rate
L3TV LASER
Ranging Command
(Laser)
FLIR
Location
NAVIGATION
Roll Stabilization
Pitch Stabilization
Test Signals
INERTIAL PLATFORM (NO. 1 & 2)
Test Commands
Platform Erection
Platform Torquemg
SATELLITE
MAGNETIC COMPASS
Magnetic Deviation
Magnetic Variation
LANDING AIDS
Mode Commands
COLISION AVOIDANCE
RADIO ALTIMETER
HEADING AND ATTITUDE REF.
AIR DATA
Anti Ice
TACAN
Frequency Command
COMMUNICATION IDENTIFICATION
DATA LINK COMMANDS & MESSAGES
Test Signals
Test Commands
Reply Messages
Target Reports
Threat Reports
Raw Video
A/C Identity
A/C Altitude
Weapon Status
Fuel Status
A/C Coordinates
A/C Speed
Engine Status
Oxygen Status
Fire Cont. Status
Discretes
SPREAD SPECTRUM AND HF
Computer Stored Data
Tape Data
Scrambled Voice
Voice
Test Signals
Test Commands
A/C Status
Position Data
Target Data
Radar IR TV Video
BOMB DAMAGE ASSESSMENT
DATA RECORDER
VIDEO RECORDER
EMP RECORDER
RADIATION RECORDER
Test Commands
Test Signals
Caution & Warning
FAILURE MONITOR & CONTROL
Qualitative Performance (All Systems)
Quantative Performance All Systems
PROPULSION
ENGINES
THROTTLES
THRUST VECTORING & REVERSERS
Test Signals
Test Commands
Ramp Command
Thrust Command
Reverser Command
Vector Command
Windmill On/Off
Start
Trim
Shutdown
Air Temperature
Oil Pressure
Ramp Position
Oil Temperature
RPM
EPR
Thrust
Bearing Temperature
Vibration (Multiple)
Oil Particle Detector
Thrust Vector Position
Reverser Position
ELECT/HYD
ALTERNATORS (1 & 2)
APU
BATTERIES
HYDRAULICS
Test Signals
Test Commands
Switching
VSCF Control
Cross Connect
Disconnect
Right Drive
Left Drive
A/C DC Power
Frequency
Quantities
Pressure
Flow
AERODYNAMIC CONTROLS
SURFACES
Test Signals
Test Commands
Trim Commands
Aileron Commands
Elevator Commands
Rudder Commands
Flaps
Spoilers
Wing Sweep
Boundary Layer
Slats
Speed Brakes
Trims
Aileron Position
Elevator Position
Rudder Position
Spoiler Position
Wing Sweep Position
Slats
LANDING GEAR
Test Signals
Test Command
Up Commands
Down Commands
Brake Commands
Nosewheel Commands
Door Commands
Engine Windmill Disable
Up Signals
Down Signals
Brake Slip
Brake Temperature
Hydraulic Pressure
Nose Wheel Steer
Weight (Each Wheel)
Door Position
FUEL SYSTEM
TANKS PUMPS & GAUGES
CG CONTROL
Test Signals
Test Commands
Pressure/Fire Suppress
Pump Commands
In Flight Refuel
Dump Fuel
Fuel Transfer Commands
Fuel Quantities
Flow Rates
Temperature
Pressure
CG Shift
INTEGRATED MASTER KEYBOARD DISPLAY MODE SELECTION FUNCTIONS
ITEMS
A/G Combat
A/A Combat
Lo Alt Cruise
Hi Alt Cruise
Climb Profile Min Time
Vn Envelope
Tavail Treqd
Climb Profile Min. Fuel
Landing Monitor
Air Data & Thrust
Navigation
Engines
Heading
Angle of Attack Pitch & Roll
Distance or Range
Mach
Gnd Speed
TAS
EAS
NAVIGATION
Total Prog Route Input
Man or DL Route Change
Dist Bearing Time to Go
Next Tgt Data
Next Check Point Data
Nav Mode Data
Gnd Speed Drift Heading
Station Keep (TCN)
Add
Delete
STORES MANAGEMENT
Stat Load Classic Del Man
Stat Load Classic Del Auto
Del Option Wpn Chosen
Del Sel Wpn Chosen
Rel Envelope Wpn Chosen
Wpn TV
Stores Rem Wpn Chosen
FMAC
Hyd
Elect
Avionics A
Avionics B
Ldg Gear Hi Lift
Oxy Status
Test Proc 1 & 2
BATTLE SITUATION
Threat α N
Threat Priority
Weapon Launch Envelopes
Friend
AAA
SAM
Gnd Indirect
A1 Pulse
A1 Pulse Doppler
Air Indirect
ENGINE
Eng Disp
N1 Epr T/T
Vib Monitor
Temp Monitor
Fuel Flow
Ramp Positions
COMM/IDENT
Preset Freq Sel
Phone Book
Msg Traffic
D/L Msg 1
D/L Msg 2
D/L Msg 3
IFF Interr Response Data
HSD
Auto Rng Expend
Nav CP's
Precision CP's
Nav Route
Waypoint Data
Short Route Home
Enroute Times
Wpn TV
Items Symbology
E2 Scan
B Scan
C Scan
Situation
Predictor
Add
Delete
Charts
Radar
Flicker
HUD/VSD
Add
Delete
Pitch & Roll Lines
Artificial Horizon
Vv
H h
Heading
Predict
Items Symbology
Flight Path Marker
BASIC PROGRAMS
Legend Change Logic
Alpha Numeric Commands
MPD Transfer Command
HSD/VSD/HUD Transfer Commands
L3TV
FLIR
Laser
Laser Spot Seeker
ATA
BDA
Wpn TV
Fixed TV
SWITCHING CIRCUITS
SIGNAL PROCESSORS BUFFERS
Items
Mission Ready
Acknowledge
FMACS Status
In Flight Test
Fire Control
Navigation
Comm Ident
Pen Aids
Stores Management
Bomb Damage
Elect Hydraulics
Landing Gear
Fuel System
Environ Control
Lighting
Airframe
Escape Capsule
Elect Hyd
Address Indirect
Address Code
HF
Freq
Channel
IFF (AG)
IFF (MMR)
Mode
Code
Voice
Data Link
Clear
Secure
Relay
Low Power
Normal Power
A
B
C
SAT
TX
RCV
ADF
Position
Hold
Zero
Emergency
Identity
Man. IFC Alt
Mach
TAS
EAS
Altitude Control
Terrain Follow
Clearance Plane
Heading
Capture
Nav Steer
AFCS On
AFCS Off
INS 1
INS 2
AHRS
Time (Z)
Radio Alt
SAT
TACAN
ILS
Align
Operate
Update
Time Sync
Align Status
Gyro Compass
TH Insert
Last Hdg
Mag Var (E)
Mag Var (W)
N Lat
S Lat
E Long
W Long
Offset
Baro Cal
Pres Position
CP
Dest
Base
To
From
MMR
SAT
D/L
E-O
TACAN
Visual

F B F



A/G Combat
A/A Combat
Lo Alt Cruise
Hi Alt Cruise
Climb Profile Min Time
V_n Envelope
Tavail - Treqd
Climb Profile - Min. Fuel
Landing Monitor
Air Data & Thrust
Navigation
Engines
Heading
Angle of Attack Pitch & Roll
Distance or Range
Mach
Gnd Speed
TAS
EAS
Total Prog Route Input
Man or DL Route Change
Dist Bearing Time to Go
Next Tgt Data
Next Check Point Data
Nav Mode Data
Gnd Speed Drift Heading
Station Keep (TCN)
Add
Delete
Stat Load Classic Del Man
Stat Load Classic Del Auto
Del Option Wpn Chosen
Del Sel Wpn Chosen
Rel Envelope Wpn Chosen
Wpn TV
Stores Rem Wpn Chosen
Hyd
Elect
Avionics A
Avionics B
Ldg Gear Hi Lift
Oxy Status
Test Proc 1 & 2
Threat α N
Threat Priority
Weapon Launch Envelopes
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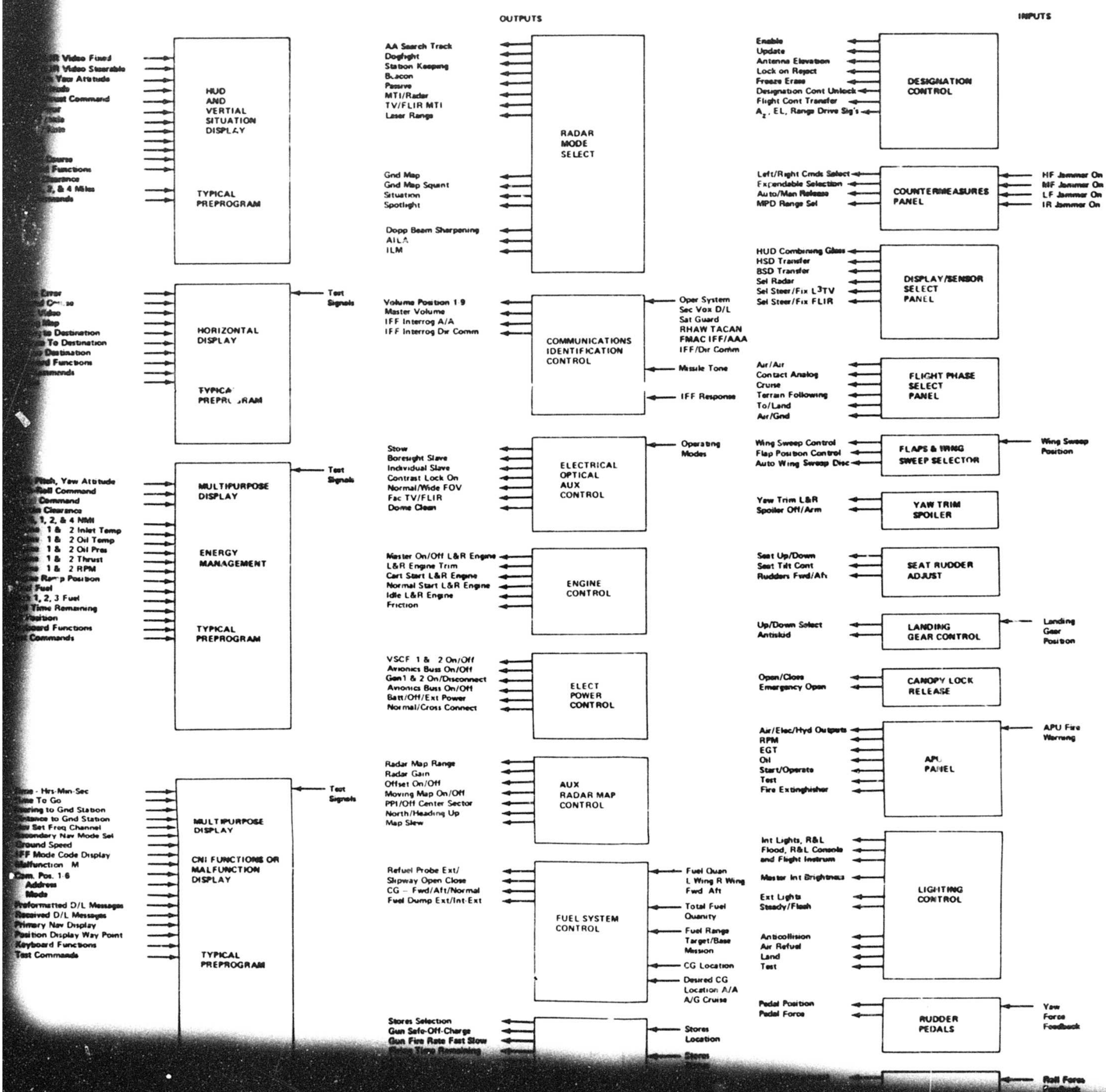
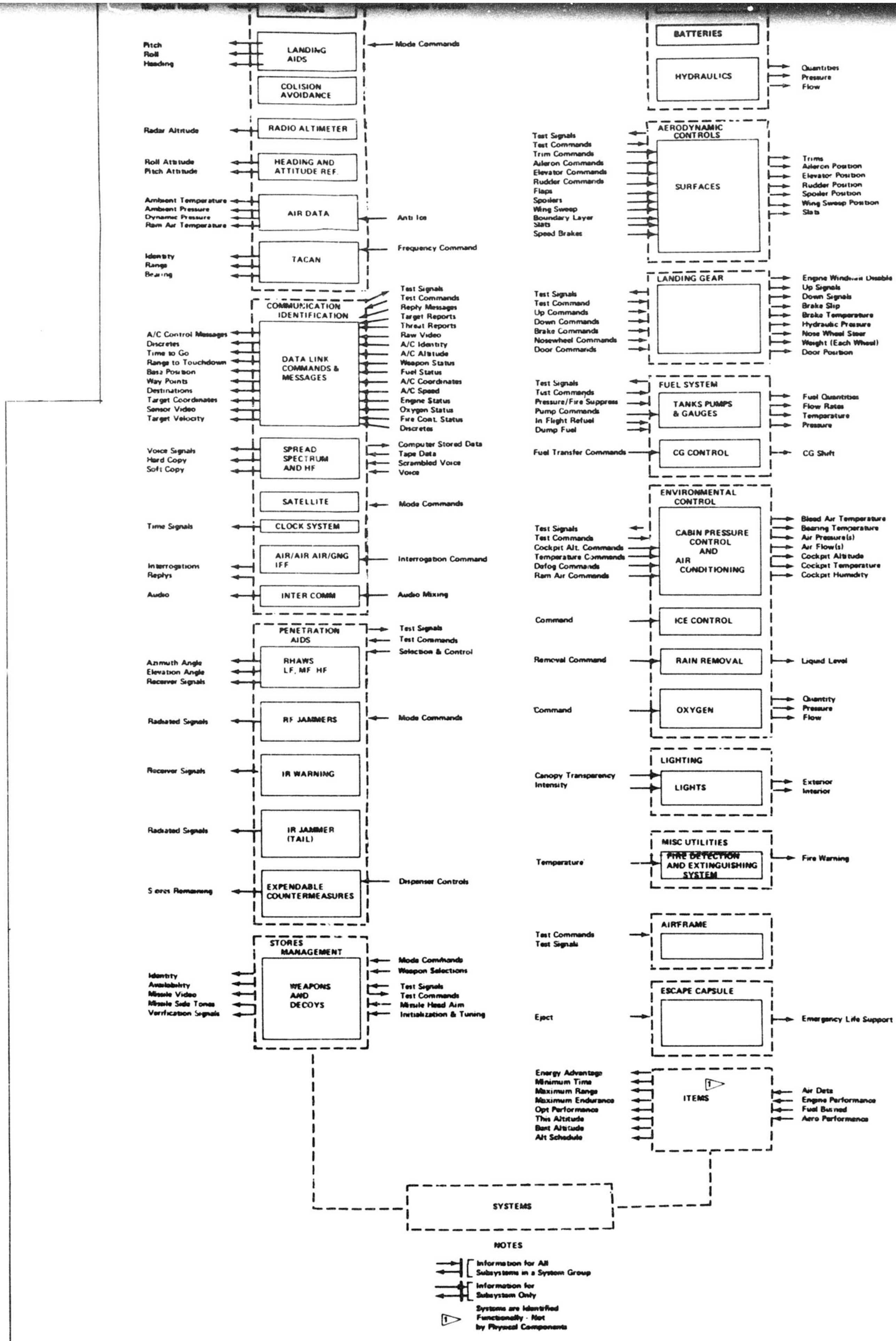
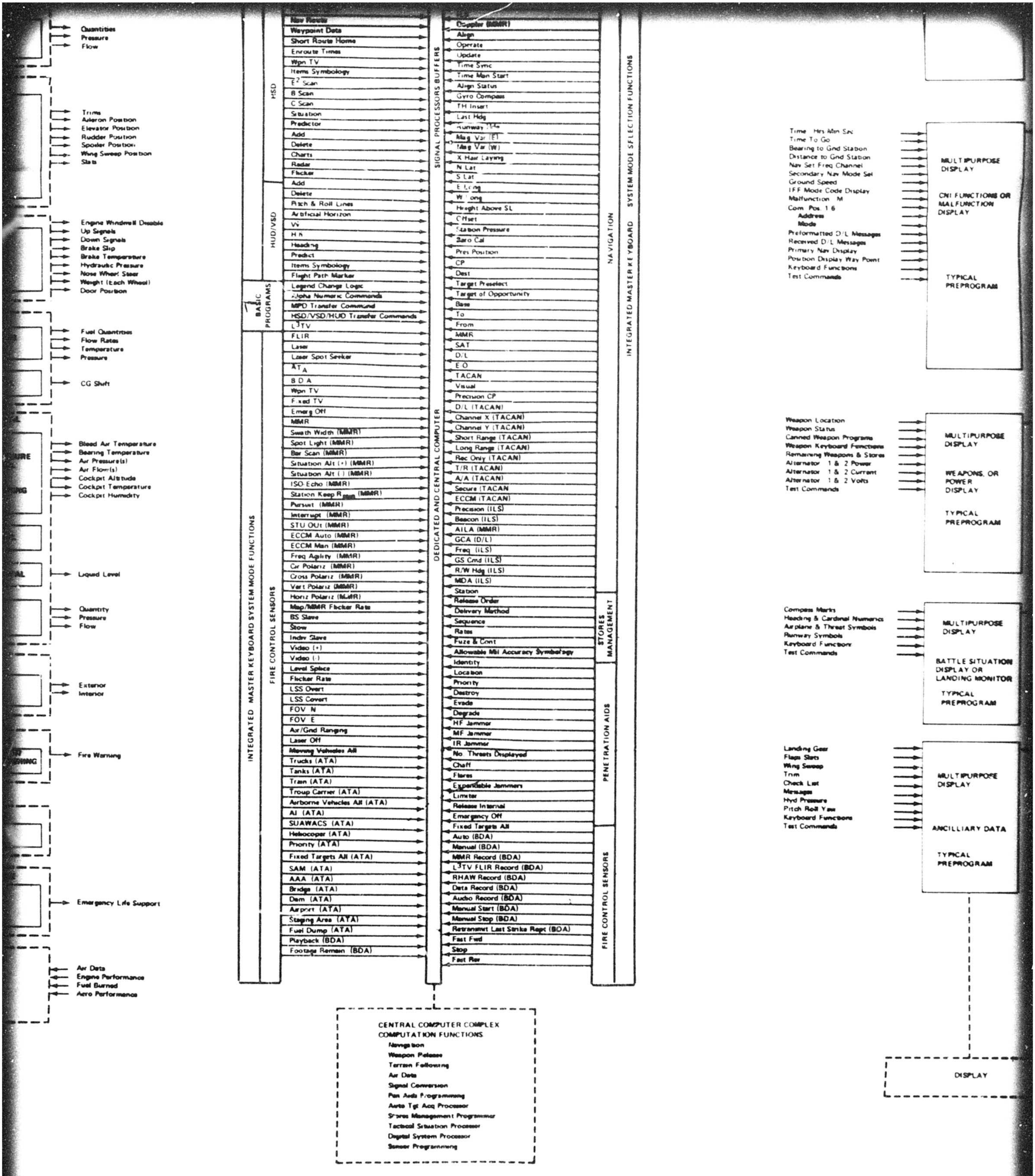
AAA
SAM
Gnd Indirect
A1 Pulse
A1 Pulse Doppler
Air Indirect
Eng Disp
N1 Epr T/T
Vib Monitor
Temp Monitor
Fuel Flow
Ramp Positions
Preset Freq Sel
Phone Book
Msg Traffic
D/L Msg 1
D/L Msg 2
D/L Msg 3
IFF Interr Response Data
Auto Rng Expand
Nav CP's
Precision CP's
Nav Route
Waypoint Data
Short Route Home
Enroute Times
Wpn TV
Items Symbology
E^2 Scan
B Scan
C Scan
Situation
Predictor
Add
Delete
Charts
Radar
Flicker
Add
Delete
Pitch & Roll Lines
Artificial Horizon
Vv
H h
Heading
Predict
Items Symbology
Flight Path Marker
Legend Change Logic
Alpha Numeric Commands
MPD Transfer Command
HSD/VSD/HUD Transfer Commands
L^3TV
HSD
HUD/VSD
SWITCHING CIRCUITS
SIGNAL PROCESSORS BUFFERS
Items
Mission Ready Test
Preflight Test
Acknowledge
FMACS Status Summary
In Flight Tests
Fire Control
Navigation
Comm Ident
Pen Aids
Stores Management
Bomb Damage Assess
Elect Hydraul
Controls/Displays
Landing Gear
Fuel System
Environ Cont
Lighting
Airframe
Escape Capsule
Elect Hyd
Address Index
Address Code
HF
Freq
Channel
IFF (AG)
IFF (MMR)
IFF (Dir Comm)
Mode
Code
Voice
Data Link
Clear
Secure
Relay
Low Power
Normal Power
A
B
C
SAT
TX
RCV
ADF
Position
Hold
Zero
Emergency
Identity
Min. IFC Alt
Mach
TAS
EAS
Altitude Command
Terrain Following
Clearance Plane Set
Heading
Capture
Nav Steer
AFCS On
AFCS Off
INS 1
INS 2
AHRS
Time (Z)
Radio Alt
SAT
TACAN
ILS
Doppler (MMR)
Align
Operate
Update
Time Sync
Time Man Start
Align Status
Gyro Compass
TH Insert
Last Hdg
Runway Hdg
Mag Var (E)
Mag Var (W)
X-Hair Laying
N Lat
S Lat
E Long
W Long
Height Above SL
Offset
Station Pressure
Baro Cal
Pres Position
CP
Dest
Target Preselect
Target of Opportunity
Base
To
From
EMAC
COMM & IDENT
ITEMS
NAVIGATION
SYSTEM MODE SELECTION FUNCTIONS
INTEGRATED MASTER KEYBOARD
INPUTS
OUTPUTS
L^3TV/FLIR Video Fixed
L^3TV/FLIR Video Steerable
Roll, Pitch Yaw Attitude
Radar Altitude
Engine Thrust Command
Course Error
Baro Altitude
Baro Alt Rate
Heading
Airspeed
Selected Course
Keyboard Functions
Terrain Clearance
at ½, 1, 2, & 4 Miles
Test Commands
HUD AND VERTICAL SITUATION DISPLAY
TYPICAL PREPROGRAM
AA Search Track
Dogfight
Station Keeping
Beacon
Passive
MTI/Radar
TV/FLIR MTI
Laser Range
Gnd Map
Gnd Map Squint
Situation
Spotlight
Dopp Beam Sharpening
AILA
ILM
RADAR MODE SELECT
Course Error
Selected Course
Radar Video
Moving Map
Bearing to Destination
Distance To Destination
Time to Destination
Keyboard Functions
Test Commands
Terrain
Test Signals
HORIZONTAL DISPLAY
TYPICAL PREPROGRAM
Volume Position 1-9
Master Volume
IFF Interrog A/A
IFF Interrog Dir Comm
COMM & IDENT CONTROL
Roll, Pitch, Yaw Attitude
Pitch-Roll Command
Speed Command
Terrain Clearance
at ½, 1, 2, & 4 NMI
Engine 1 & 2 Inlet Temp
Engine 1 & 2 Oil Temp
Engine 1 & 2 Oil Pres
Engine 1 & 2 Thrust
Engine 1 & 2 RPM
Engine Ramp Position
Total Fuel
Tank 1, 2, 3 Fuel
Fuel Time Remaining
CG Position
Keyboard Functions
Test Commands
Test Signals
MULTIPURPOSE DISPLAY
ENERGY MANAGEMENT
TYPICAL PREPROGRAM
Stow
Boresight Slave
Individual Slave
Contrast Lock On
Normal/Wide FOV
Fac TV/FLIR
Dome Clean
ELEC OPT AUX CONT
Master On/Off L&R Engine
L&R Engine Trim
Cart Start L&R Engine
Normal Start L&R Engine
Idle L&R Engine
Friction
VSCF 1 & 2 On/Off
Avionics Buss On/Off
Gen 1 & 2 On/Disconnect
Avionics Buss On/Off
Batt/Off/Ext Power
Normal/Cross Connect
Time - Hrs-Min-Sec
Time To Go
Bearing to Gnd Station
Distance to Gnd Station
Nav Set Freq Channel
Secondary Nav Mode Sel
Ground Speed
IFF Mode Code Display
Malfunction M
Com. Pos. 1-6
Address
Mode
Preformatted D/L Messages
Received D/L Messages
Primary Nav Display
Position Display Way Point
Keyboard Functions
Test Commands
Test Signals
MULTIPURPOSE DISPLAY
CNI FUNCTIONS OR MALFUNCTION DISPLAY
TYPICAL PREPROGRAM
Radar Map Range
Radar Gain
Offset On/Off
Moving Map On/Off
PPI/Off Center Sector
North/Heading Up
Map Slew
Refuel Probe Ext/
Slipway Open Close
CG – Fwd/Aft/Normal
Fuel Dump Ext/Int-Ext
Stores Selection
Gun Safe-Off-Charge
Gun Fire Rate Fast Slow



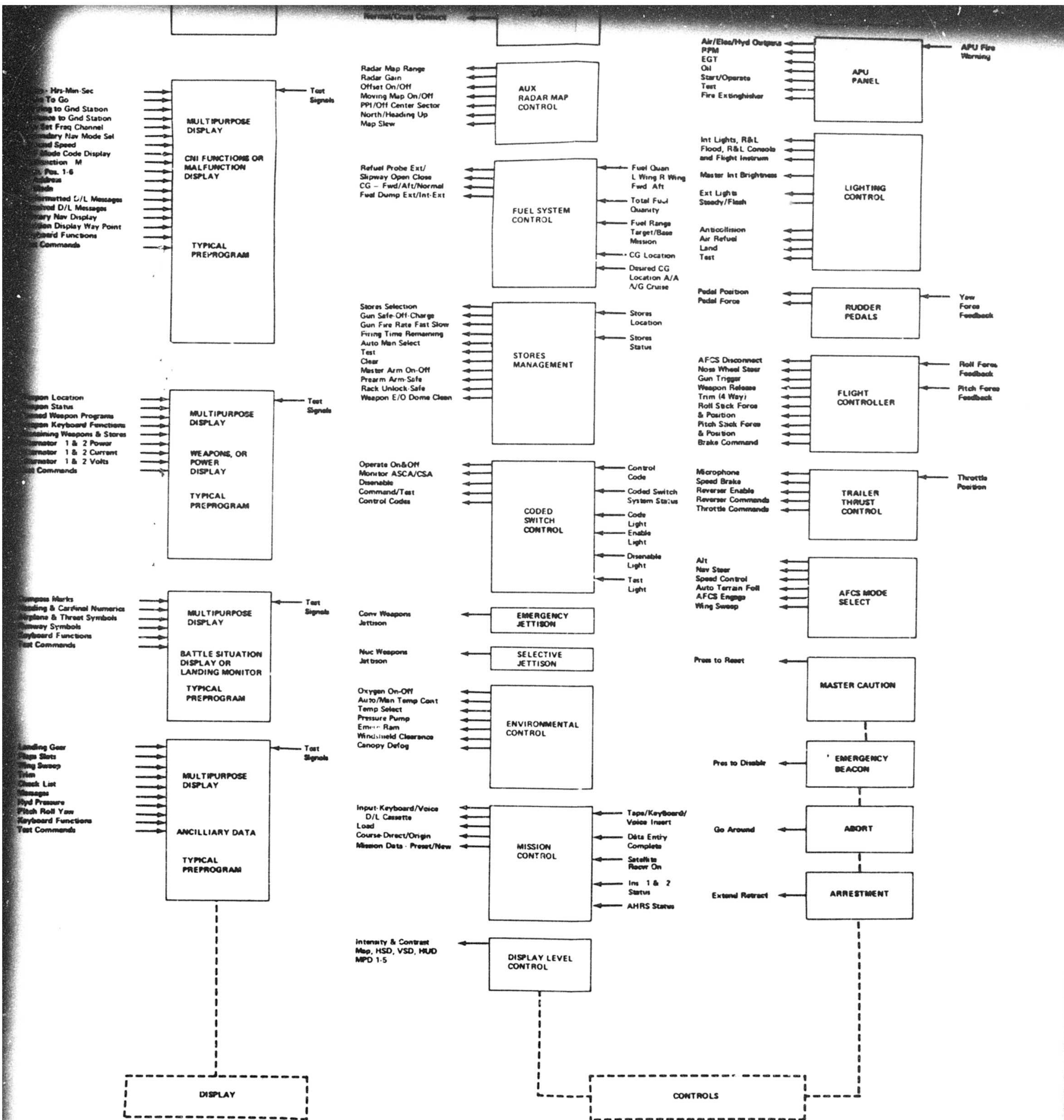
OUTPUTS
INPUTS
HUD AND VERTICAL SITUATION DISPLAY
TYPICAL PREPROGRAM
HORIZONTAL DISPLAY
Test Signals
MULTIPURPOSE DISPLAY
ENERGY MANAGEMENT
TYPICAL PREPROGRAM
MULTIPURPOSE DISPLAY
CNI FUNCTIONS OR MALFUNCTION DISPLAY
TYPICAL PREPROGRAM
Time To Go
Bearing to Gnd Station
Distance to Gnd Station
Secondary Nav Mode Sel
Ground Speed
IFF Mode Code Display
Malfunction M
Com. Pos. 1-6
Address
Mode
Preformatted D/L Messages
Received D/L Messages
Primary Nav Display
Position Display Way Point
Keyboard Functions
Test Commands
AA Search Track
Dogfight
Station Keeping
Beacon
Passive
MTI/Radar
TV/FLIR MTI
Laser Range
RADAR MODE SELECT
Gnd Map
Gnd Map Squint
Situation
Spotlight
Dopp Beam Sharpening
ILM
Volume Position 1-9
Master Volume
IFF Interrog A/A
IFF Interrog Dir Comm
COMMUNICATIONS IDENTIFICATION CONTROL
Oper System
Sec Vox D/L
Sat Guard
RHAW TACAN
FMAC IFF/AAA
IFF/Dir Comm
Missile Tone
IFF Response
Stow
Boresight Slave
Individual Slave
Contrast Lock On
Normal/Wide FOV
Fac TV/FLIR
Dome Clean
ELECTRICAL OPTICAL AUX CONTROL
Operating Modes
Master On/Off L&R Engine
L&R Engine Trim
Cart Start L&R Engine
Normal Start L&R Engine
Idle L&R Engine
Friction
ENGINE CONTROL
VSCF 1 & 2 On/Off
Avionics Buss On/Off
Gen 1 & 2 On/Disconnect
Avionics Buss On/Off
Batt/Off/Ext Power
Normal/Cross Connect
ELECT POWER CONTROL
Radar Map Range
Radar Gain
Offset On/Off
Moving Map On/Off
PPI/Off Center Sector
North/Heading Up
Map Slew
AUX RADAR MAP CONTROL
Refuel Probe Ext/
Slipway Open Close
CG – Fwd/Aft/Normal
Fuel Dump Ext/Int-Ext
FUEL SYSTEM CONTROL
Fuel Quan
L Wing R Wing
Fwd Aft
Total Fuel Quanity
Fuel Range Target/Base Mission
CG Location
Desired CG Location A/A A/G Cruise
Stores Selection
Gun Safe-Off-Charge
Gun Fire Rate Fast Slow
Stores Location
Enable
Update
Antenna Elevation
Lock on Reject
Freeze Erase
Designation Cont Unlock
Flight Cont Transfer
A_z, EL, Range Drive Sig's
DESIGNATION CONTROL
Left/Right Cmds Select
Expendable Selection
Auto/Man Release
MPD Range Sel
COUNTERMEASURES PANEL
HF Jammer On
MF Jammer On
LF Jammer On
IR Jammer On
HUD Combining Glass
HSD Transfer
BSD Transfer
Sel Radar
Sel Steer/Fix L^3TV
Sel Steer/Fix FLIR
DISPLAY/SENSOR SELECT PANEL
Air/Air
Contact Analog
Cruise
Terrain Following
To/Land
Air/Gnd
FLIGHT PHASE SELECT PANEL
Wing Sweep Control
Flap Position Control
Auto Wing Sweep Disc
FLAPS & WING SWEEP SELECTOR
Wing Sweep Position
Yaw Trim L&R
Spoiler Off/Arm
YAW TRIM SPOILER
Seat Up/Down
Seat Tilt Cont
Rudders Fwd/Aft
SEAT RUDDER ADJUST
Up/Down Select
Antiskid
LANDING GEAR CONTROL
Landing Gear Position
Open/Close
Emergency Open
CANOPY LOCK RELEASE
Air/Elec/Hyd Outputs
RPM
EGT
Oil
Start/Operate
Test
Fire Extinghisher
APU PANEL
APU Fire Warning
Int Lights, R&L
Flood, R&L Console and Flight Instrum
Master Int Brightness
Ext Lights Steady/Flash
Anticollision
Air Refuel
Land
Test
LIGHTING CONTROL
Pedal Position
Pedal Force
RUDDER PEDALS
Yaw Force Feedback
Roll Force

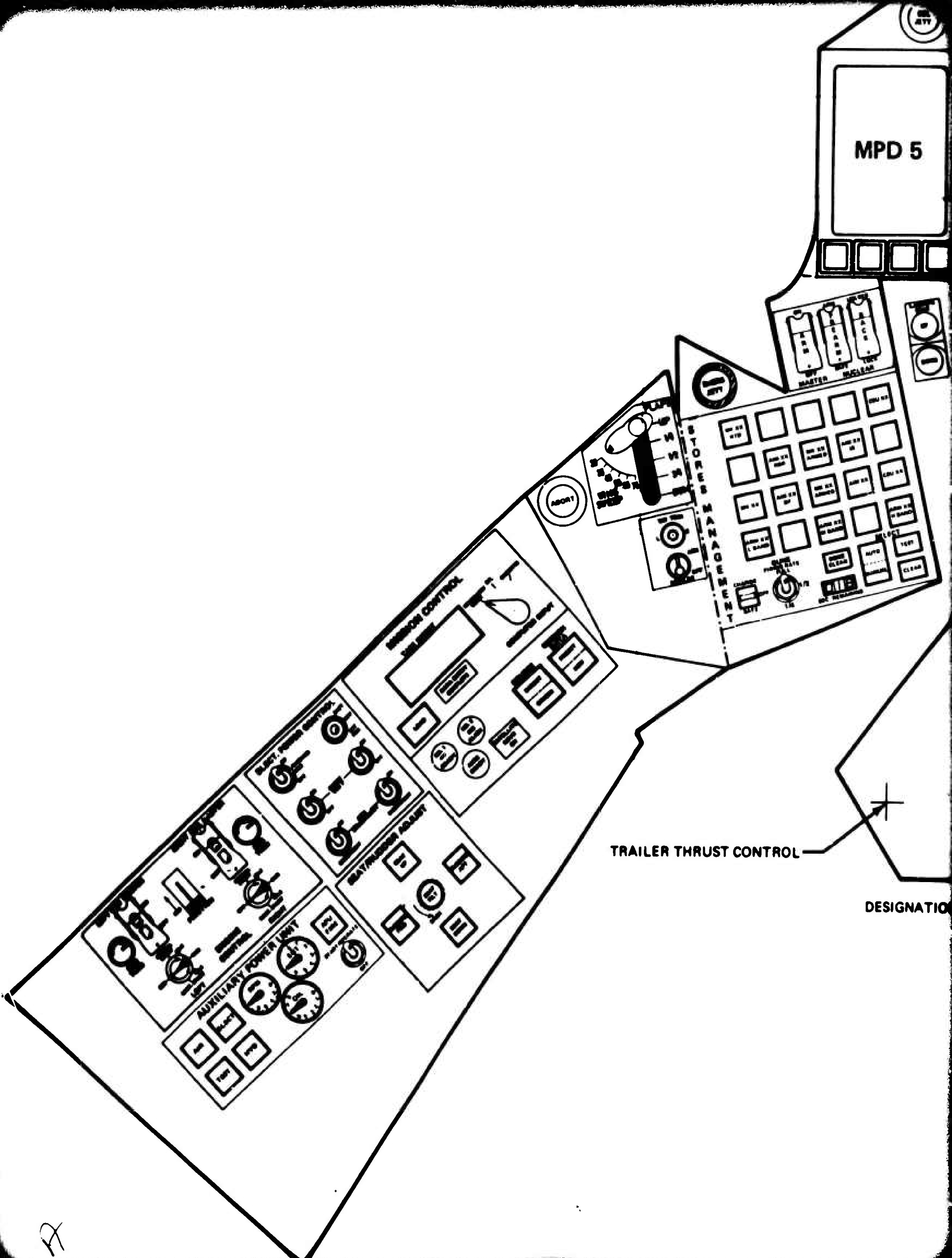


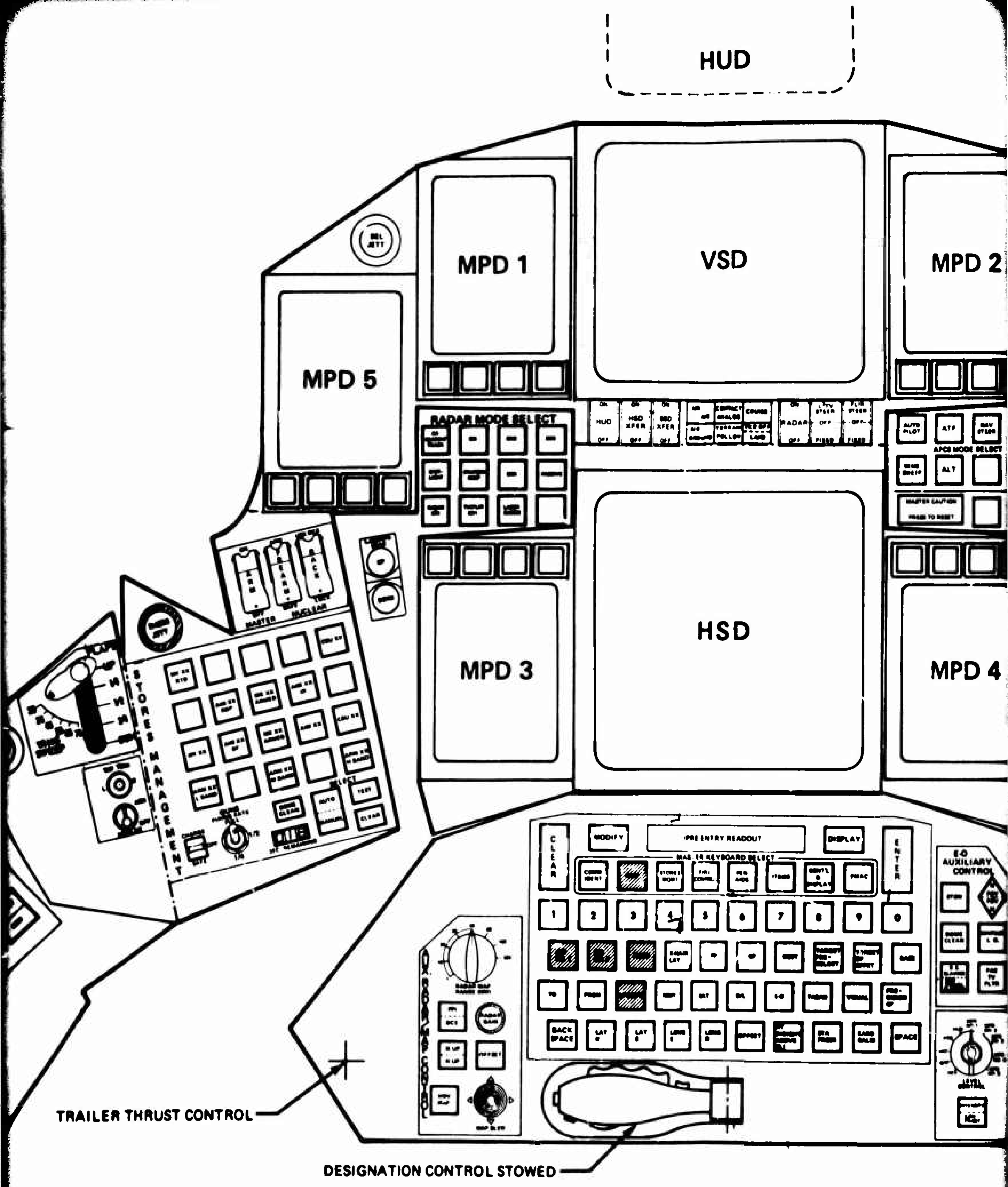
COMPASS
Magnetic Heading
Magnetic Variation
LANDING AIDS
Pitch
Roll
Heading
Mode Commands
COLISION AVOIDANCE
RADIO ALTIMETER
Radar Altitude
HEADING AND ATTITUDE REF.
Roll Attitude
Pitch Attitude
AIR DATA
Ambient Temperature
Ambient Pressure
Dynamic Pressure
Ram Air Temperature
Anti Ice
TACAN
Identity
Range
Bearing
Frequency Command
COMMUNICATION IDENTIFICATION
DATA LINK COMMANDS & MESSAGES
A/C Control Messages
Discretes
Time to Go
Range to Touchdown
Base Position
Way Points
Destinations
Target Coordinates
Sensor Video
Target Velocity
Test Signals
Test Commands
Reply Messages
Target Reports
Threat Reports
Raw Video
A/C Identity
A/C Altitude
Weapon Status
Fuel Status
A/C Coordinates
A/C Speed
Engine Status
Oxygen Status
Fire Cont. Status
Discretes
SPREAD SPECTRUM AND HF
Voice Signals
Hard Copy
Soft Copy
Computer Stored Data
Tape Data
Scrambled Voice
Voice
SATELLITE
Mode Commands
CLOCK SYSTEM
Time Signals
AIR/AIR AIR/GNG IFF
Interrogations
Replys
Interrogation Command
INTER COMM
Audio
Audio Mixing
PENETRATION AIDS
Test Signals
Test Commands
Selection & Control
RHAWS LF, MF HF
Azimuth Angle
Elevation Angle
Receiver Signals
RF JAMMERS
Radiated Signals
Mode Commands
IR WARNING
Receiver Signals
IR JAMMER (TAIL)
Radiated Signals
EXPENDABLE COUNTERMEASURES
Stores Remaining
Dispenser Controls
STORES MANAGEMENT
WEAPONS AND DECOYS
Identity
Availability
Missile Video
Missile Side Tones
Verification Signals
Mode Commands
Weapon Selections
Test Signals
Test Commands
Missile Head Aim
Initialization & Tuning
BATTERIES
HYDRAULICS
Quantities
Pressure
Flow
AERODYNAMIC CONTROLS
SURFACES
Test Signals
Test Commands
Trim Commands
Aileron Commands
Elevator Commands
Rudder Commands
Flaps
Spoilers
Wing Sweep
Boundary Layer
Slats
Speed Brakes
Trims
Aileron Position
Elevator Position
Rudder Position
Spoiler Position
Wing Sweep Position
Slats
LANDING GEAR
Test Signals
Test Command
Up Commands
Down Commands
Brake Commands
Nosewheel Commands
Door Commands
Engine Windmill Disable
Up Signals
Down Signals
Brake Slip
Brake Temperature
Hydraulic Pressure
Nose Wheel Steer
Weight (Each Wheel)
Door Position
FUEL SYSTEM
TANKS PUMPS & GAUGES
Test Signals
Test Commands
Pressure/Fire Suppress
Pump Commands
In Flight Refuel
Dump Fuel
Fuel Quantities
Flow Rates
Temperature
Pressure
CG CONTROL
Fuel Transfer Commands
CG Shift
ENVIRONMENTAL CONTROL
CABIN PRESSURE CONTROL AND AIR CONDITIONING
Test Signals
Test Commands
Cockpit Alt. Commands
Temperature Commands
Defog Commands
Ram Air Commands
Bleed Air Temperature
Bearing Temperature
Air Pressure(s)
Air Flow(s)
Cockpit Altitude
Cockpit Temperature
Cockpit Humidity
ICE CONTROL
Command
RAIN REMOVAL
Removal Command
Liquid Level
OXYGEN
Command
Quantity
Pressure
Flow
LIGHTING
LIGHTS
Canopy Transparency
Intensity
Exterior
Interior
MISC UTILITIES
FIRE DETECTION AND EXTINGUISHING SYSTEM
Temperature
Fire Warning
AIRFRAME
Test Commands
Test Signals
ESCAPE CAPSULE
Eject
Emergency Life Support
ITEMS
1
Energy Advantage
Minimum Time
Maximum Range
Maximum Endurance
Opt Performance
This Altitude
Best Altitude
Alt Schedule
Air Data
Engine Performance
Fuel Burned
Aero Performance
SYSTEMS
NOTES
Information for All Subsystems in a System Group
Information for Subsystem Only
1
Systems are Identified Functionally - Not by Physical Components



IIPACS INTERFACE DIAGRAM

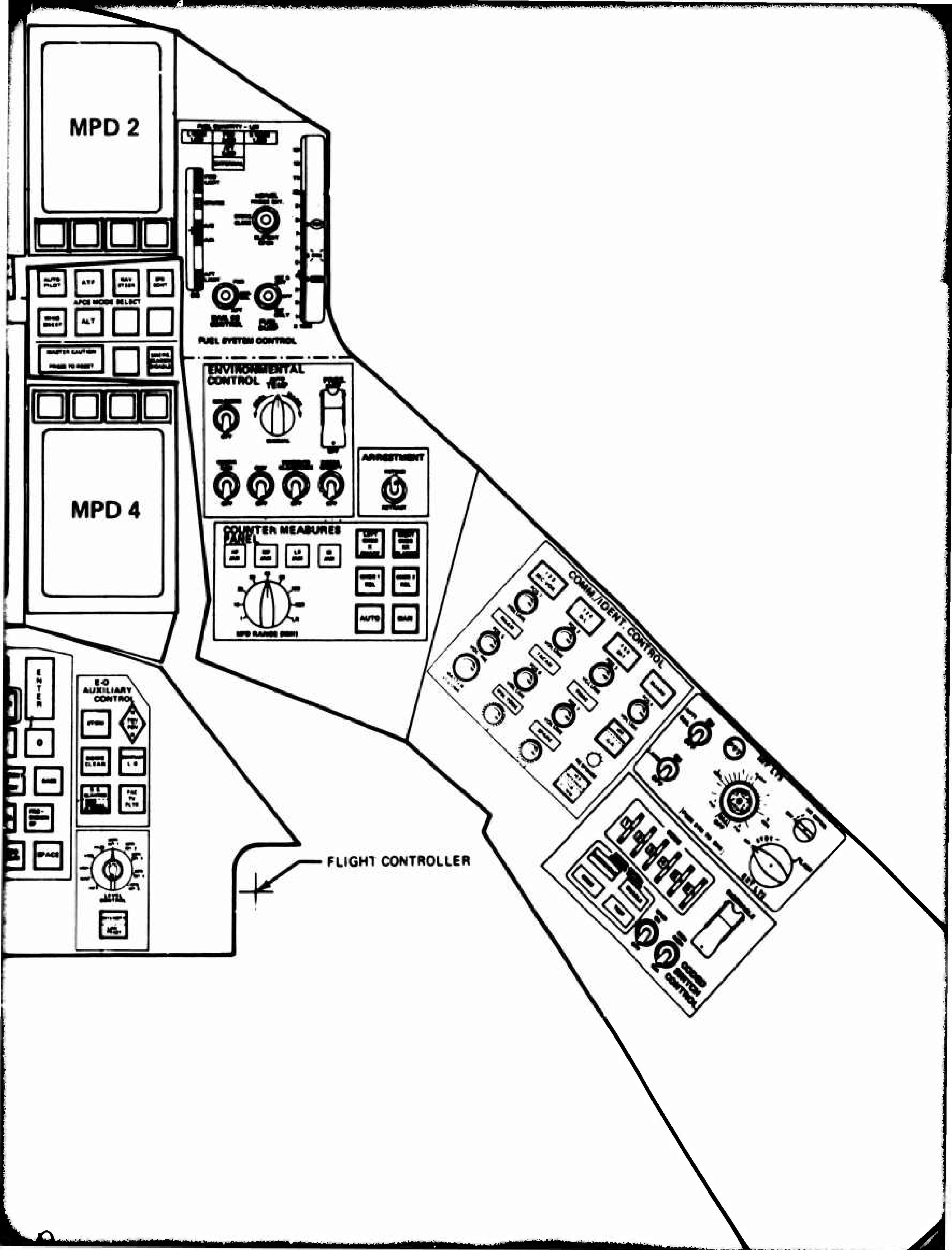

Normal/Cross Connect
MULTIPURPOSE DISPLAY
CNI FUNCTIONS OR MALFUNCTION DISPLAY
TYPICAL PREPROGRAM
Test Signals
Hrs-Min-Sec
To Go
to Gnd Station
to Gnd Station
Freq Channel
Nav Mode Sel
Speed
Mode Code Display
D/L Messages
D/L Messages
Nav Display
Display Way Point
Functions
Commands
AUX RADAR MAP CONTROL
Radar Map Range
Radar Gain
Offset On/Off
Moving Map On/Off
PPI/Off Center Sector
North/Heading Up
Map Slew
APU PANEL
Air/Elec/Hyd Outputs
RPM
EGT
Oil
Start/Operate
Test
Fire Extinghisher
APU Fire Warning
FUEL SYSTEM CONTROL
Refuel Probe Ext/
Slipway Open Close
CG – Fwd/Aft/Normal
Fuel Dump Ext/Int-Ext
Fuel Quan
L Wing R Wing
Fwd Aft
Total Fuel Quantity
Fuel Range
Target/Base
Mission
CG Location
Desired CG
Location A/A
A/G Cruise
LIGHTING CONTROL
Int Lights, R&L
Flood, R&L Console
and Flight Instrum
Master Int Brightness
Ext Lights
Steady/Flash
Anticollision
Air Refuel
Land
Test
RUDDER PEDALS
Pedal Position
Pedal Force
Yaw Force Feedback
STORES MANAGEMENT
Stores Selection
Gun Safe-Off-Charge
Gun Fire Rate Fast Slow
Firing Time Remaining
Auto Man Select
Test
Clear
Master Arm On-Off
Prearm Arm-Safe
Rack Unlock-Safe
Weapon E/O Dome Clean
Stores Location
Stores Status
MULTIPURPOSE DISPLAY
WEAPONS, OR POWER DISPLAY
TYPICAL PREPROGRAM
Test Signals
Location
Status
Weapon Programs
Keyboard Functions
Weapons & Stores
1 & 2 Power
1 & 2 Current
1 & 2 Volts
Commands
FLIGHT CONTROLLER
AFCS Disconnect
Nose Wheel Steer
Gun Trigger
Weapon Release
Trim (4 Way)
Roll Stick Force
& Position
Pitch Stick Force
& Position
Brake Command
Roll Force Feedback
Pitch Force Feedback
CODED SWITCH CONTROL
Operate On&Off
Monitor ASCA/CSA
Disenable
Command/Test
Control Codes
Control Code
Coded Switch System Status
Code Light
Enable Light
Disenable Light
Test Light
TRAILER THRUST CONTROL
Microphone
Speed Brake
Reverser Enable
Reverser Commands
Throttle Commands
Throttle Position
AFCS MODE SELECT
Alt
Nav Steer
Speed Control
Auto Terrain Foll
AFCS Engage
Wing Sweep
MULTIPURPOSE DISPLAY
BATTLE SITUATION DISPLAY OR LANDING MONITOR
TYPICAL PREPROGRAM
Test Signals
Marks
& Cardinal Numerics
& Threat Symbols
Symbols
Functions
Commands
EMERGENCY JETTISON
Conv Weapons Jettison
SELECTIVE JETTISON
Nuc Weapons Jettison
MASTER CAUTION
Press to Reset
ENVIRONMENTAL CONTROL
Oxygen On-Off
Auto/Man Temp Cont
Temp Select
Pressure Pump
Windshield Clearance
Canopy Defog
EMERGENCY BEACON
Pres to Disable
MULTIPURPOSE DISPLAY
ANCILLIARY DATA
TYPICAL PREPROGRAM
Test Signals
Landing Gear
Flaps Slots
Wing Sweep
Trim
Check List
Hyd Pressure
Pitch Roll Yaw
Keyboard Functions
Test Commands
MISSION CONTROL
Input-Keyboard/Voice
D/L Cassette
Load
Course-Direct/Origin
Mission Data - Preset/New
Tape/Keyboard/Voice Insert
Data Entry Complete
Satellite Recvr On
Ins 1 & 2 Status
AHRS Status
ABORT
Go Around
ARRESTMENT
Extend Retract
DISPLAY LEVEL CONTROL
Intensity & Contrast
Map, HSD, VSD, HUD
MPD 1-5
DISPLAY
CONTROLS

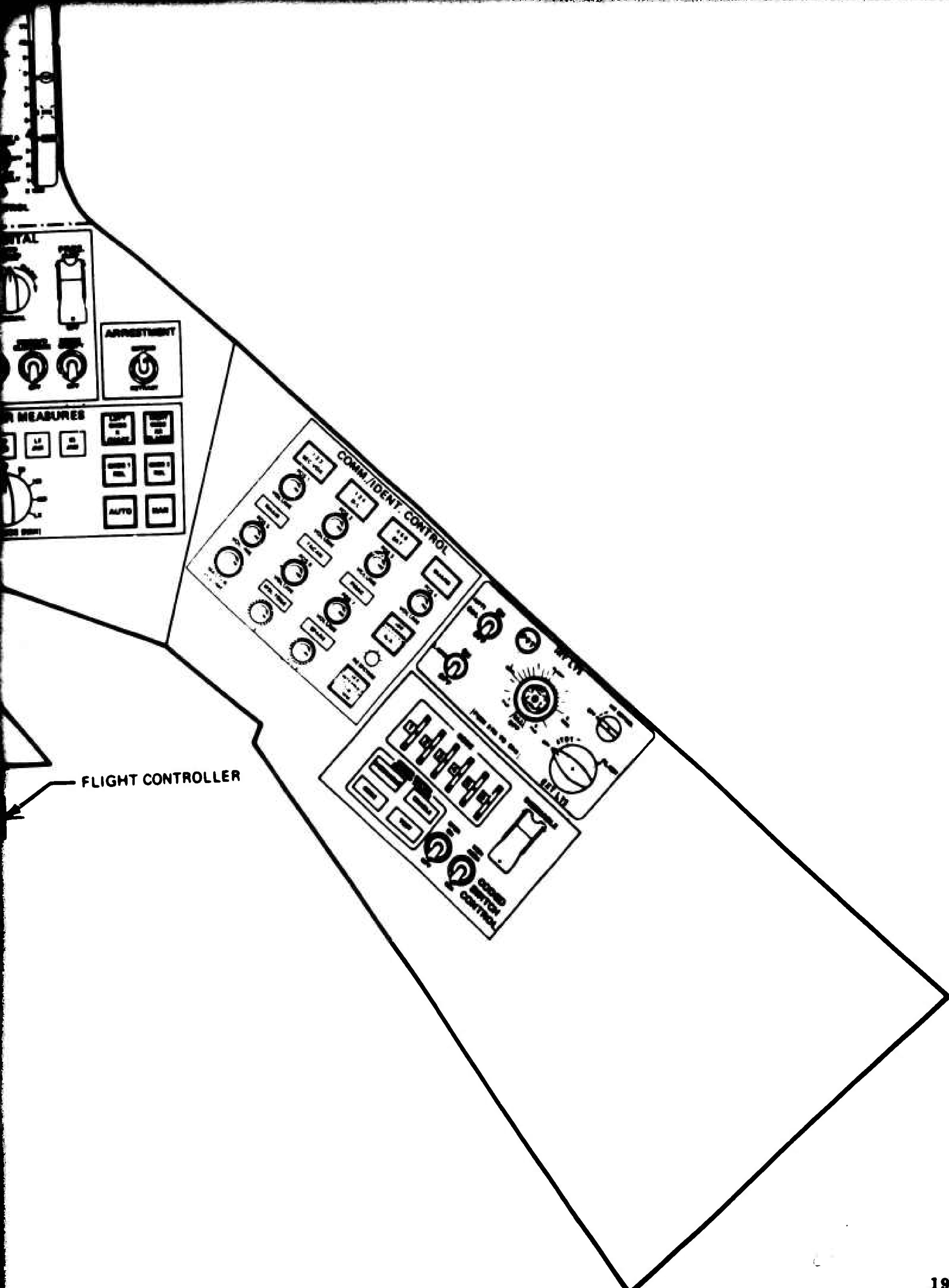

MPD 5
STORES MANAGEMENT
ABORT
AUXILIARY POWER UNIT
TRAILER THRUST CONTROL
DESIGNATIO



HUD
MPD 1
VSD
MPD 2
MPD 5
RADAR MODE SELECT
HSD
MPD 3
MPD 4
STORES MANAGEMENT
CLEAR
MODIFY
PRE ENTRY READOUT
DISPLAY
ENTER
MASTER KEYBOARD SELECT
E-O AUXILIARY CONTROL
TRAILER THRUST CONTROL
DESIGNATION CONTROL STOWED

B


MPD 2
FUEL SYSTEM CONTROL
ENVIRONMENTAL CONTROL
ARRESTMENT
COUNTER MEASURES PANEL
AUTO
MPD 4
COMM/IDENT. CONTROL
E-O AUXILIARY CONTROL
ENTER
SPACE
FLIGHT CONTROLLER


ARRESTMENT
MEASURES
AUTO
COMM./IDENT. CONTROL
CODED
MOTOR
CONTROL
FLIGHT CONTROLLER